DISCOVERY

This minute jellyfish (medusa) called *Gonionemus* has suckered tentacles enabling it to capture animals as large as itself. (See article "Medusae and Zoophytes".)

SEPTEMBER 1954 2/-

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION AT OXFORD

This year's British Association at Oxford promises to be a good meeting. There is general agreement that the programme looks decidedly better than average, a fact which will not go unnoticed by the Press, which is like to give the meeting a better-than-average coverage. (Incidentally, television will be taking note of the B.A.'s existence —for the first time.)

Elsewhere in this issue we print the full text of Dr. Adrian's presidential address. We particularly welcome his remarks about the social sciences, which are sadly in need of encouragement in Britain, as was pointed out in our first editorial of June 1954. The Unesco report (entitled *The Teaching of the Social Sciences in the United Kingdom*) which we mentioned in that issue made it only too clear that sociological studies are poorly supported by British universities. One reason for this lack of support is the way in which social sciences are disregarded by natural scientists in general. For example, there is only a very slim chance that a social scientist will be nominated for an F.R.S., and the chance of one ever being *elected* to fellowship of the Royal Society is slender in the extreme. One might say with justice that the social prestige which such scientists enjoy is no higher than the prestige which Britain accords to her grammar school science masters, and the effect of this is extremely serious. The social consequences of the progress of science and technology spell new problems that require the attention of social scientists at the time when they first appear on our troubled earth. 'Too little and too late' sums up Britain's current neglectful policy towards sociology. The sociologists' approach must be brought to bear upon the social problems not only of Britain but of the whole Commonwealth if we want to be able to maintain the claim that Britain gives adequate support to science as a whole.

Dr. Adrian's words about the importance of the social sciences will carry great weight, for he is president of the Royal Society as well as of the British Association, and we feel sure that his address will start the ball rolling in the right direction. Awareness of a deficiency is the first step towards the correction of that deficiency; it will take time to remedy this particular blind spot, but when eventually this has been done, and when at long last the social sciences start to receive their due measure of support and active encouragement, people will look back and recognise that the 1954 B.A. presidential address was an important incident in the history of the development of this field of British science.

* * *

The arrival of the British Association's programme for the Oxford meeting comes as a reminder of the previous meetings held in this city.

The 'British Ass' first met in Oxford in 1832. To quote this year's programme, that meeting "marked the real debut of the Association and determined its basic pattern". The president was Dr. William Buckland. A theologian who took up science 'as a relaxation', he had a dual career reminiscent of Roger Bacon and Robert Grosseteste, who were also Oxford men. Buckland was canon of Christ Church, and later became Dean of Westminster. On the scientific side, he was reader in both mineralogy and geology from the foundation of those two Chairs (in 1813 and 1818 respectively) by the Prince Regent. His scientific work, which was resented by the orthodox clergy because his discoveries seemed to conflict with the traditional ideas about 'the Creation and the Flood', was an inspiration to Oxford undergraduates, and few would dispute the judgment that "the man who did more than any other before 1850 to popularise science in Oxford was Dr. Buckland".

His services to the British Association were likewise considerable. Sir Roderick Murchison, the geologist, recorded of the 1832 meeting that "under the presidency of Buckland, that body was then licked into shape, and divided into six sections. As the mass of the great guns of the metropolis had now joined us, and also Sedgwick, Whewell and the best men of Cambridge, our success was assured. Altogether it was (thanks to its proposer, Daubeny) a most auspicious meeting, the more so as it terminated with an invitation for the next year from Cambridge, with my dear colleague, Adam Sedgwick, as *praeses* [president]."

It would be a mistake to think that everyone felt as happy about that meeting as did Murchison. John Keble, who was one of the great leaders of university thought, took a very different line from the scientific enthusiasts. In a letter to a friend, he bitterly complained that the honorary degree of D.C.L. had been bestowed on some of the most distinguished members of the 1832 B.A. meeting: "The Oxford Doctors have truckled sadly to the spirit of the times in receiving the hodge-podge of philosophers as they did." The 'hodge-podge' included the distinguished names of Brewster, Faraday, Dalton and Robert Brown, the botanist.

The official history of the British Association published in 1931 remarks that this sally of Mr. Keble's was "no passing or accidental caprice. It represented a deep-seated sentiment in this place of learning, which had its origin in historic causes, and which has only died out in our time. One potent cause of it was that both bodies [the University and the British Association] were teachers of science, but did not then in any degree attach the same meaning to that word." The burden of that last remark can perhaps best be appreciated if one remembers that Charles Babbage had only just published his famous pamphlet entitled *Reflections on the Decline of Science in England*, which included an indictment of the current neglect of science in Oxford and Cambridge.

Between the 1832 and the 1847 Oxford meetings, the British Association had become well established and had travelled widely, visiting Edinburgh, Glasgow and Dublin as well as the most important English cities. The 1847 meeting, which was presided over by Sir Robert Harry Inglis, F.R.S. and M.P. for Oxford University, was scientifically most interesting for the paper which Joule delivered. In 1843 and again in 1845 Joule had lectured to the British Association, but his words had evoked an almost negligible response. His 1847 paper met with an almost similar fate—'the silence of disapproval'—but it did register with one young man who heard it—William Thomson, later to become Lord Kelvin. The president of the section had rather chilled Joule by requesting him to keep his paper short and confine his account to a brief verbal description of his experiments on the mechanical equivalent of heat. He was somewhat encouraged by the sight of Faraday sitting among the audience, but as he talked his way through his paper the conviction grew upon him that his listeners were not greatly interested in what he had to tell them. Thomson, however, realised the full significance of Joule's work, and after the meeting he discussed the matter with him. With regard to this paper, Thomson later wrote that Faraday "was much struck with it, but did not enter fully into the new views", which comment he followed up with this sentence: *It was many years after that before any of the scientific chiefs began to give their adhesion.* This incident, which exemplifies the value of British Association in bringing scientists into close personal contact and so fostering the transmission of new ideas by word of mouth, was the beginning of one important life-long friendship, a friendship which was to prove professionally valuable to both Joule and Kelvin.

The chilly reception which Joule received from most of his scientific confrères was paralleled by the reception of the British Association as a whole by the members of Oxford University. According to Lyell, very few of the college heads attended: "Out of twenty-four heads of houses, only four at Oxford to receive the Association! But it will go off the better by the absence of the lukewarm or the hostile." (The same letter contains an interesting reference to Ruskin: "I was glad . . . to see more of Ruskin, who is secretary of our Geological Section. I like him very much." It is worth noting, incidentally, that in those days geology was always very well represented at the British Association.)

Things had changed tremendously by 1860, the year of the British Association's next meeting in Oxford. By now the organisation was well in its stride, and the scientists were conscious that they were pace-makers in intellectual matters. Such was the general background to the historic clash between Wilberforce (then Bishop of Oxford) and T. H. Huxley. No shorthand writer was present to record the exact words that Huxley used on that occasion, but the account given by Dr. Vernon Harcourt to the biographer of Hooker and Huxley is probably very close to the actual truth—certainly it provides a very plausible general impression of the incident, which is consistent with other accounts:

> "If I am asked whether I would choose to be descended from the poor animal of low intelligence and stooping gait, who grins and chatters as we pass, or from a man, endowed with great ability and a splendid position, who should use these gifts to discredit and crush humble seekers after truth, I hesitate what answer to make." Hooker followed up this castigation of the bishop, and as he wrote to Darwin, "hit him in the wind at the first shot in ten words taken from his own ugly mouth". We are free to conjecture as to the validity of the narrative in the biography of the bishop himself, which thus records the episode: "The bishop . . . made a long and eloquent speech condemning Mr. Darwin's theory as unphilosophical and as founded on fancy. . . . In the course of this speech, which made a great impression, the bishop said that whatever certain people might believe, he would not look at the monkeys in the Zoological Gardens as connected with his ancestors, a remark that drew from a certain learned professor the retort, 'I would rather be descended from an ape than a bishop.' "

After that meeting, a good many years elapsed—34 years to be precise—before the British Association returned to Oxford. At the 1894 meeting the president was Robert Gascoigne-Cecil, Marquis of Salisbury. (In the second half of the 19th century many of the B.A. presidents were not professional scientists, it should be noted.) Perhaps the most interesting single item in the programme was the first public demonstration of wireless The scientist concerned was Sir Oliver Lodge, who transmitted signals over several hundred yards; he effected "the reception of Morse signals by the long and short deflections of a Thomson marine-signalling galvanometer, such as had been used in cable telegraphy. Thus was revealed the possibility of signalling by means of Clerk Maxwell's and Hertz's electromagnetic waves, although the name of 'wireless telegraphy' was introduced only in 1896 by Marconi, when its practice was begun in the face of many difficulties, initially with the help of the Post Office authorities in this country." Other notable items in the 1894 programme were the Cretan pictographs of Sir Arthur Evans, Lord Rayleigh's announcement of the discovery of argon, and Strasburger's generalisation on the reduction division of chromosomes.

The last time the B.A. met at Oxford was in 1926, when the present Duke of Windsor (then Prince of Wales) presided. The membership was 3296, and there is a fair chance that this year's attendance will rival that figure.

VERTICAL TAKE-OFF

For over fifty years, since the first flight of Wilbur and Orville Wright in December 1903, the aeroplane has depended on its forward speed along the ground for its 'lift' into the air. Thus we have seen the aeroplane go from grass fields to vast concrete runways; aerodromes like Hendon and Croydon, each in their day London's principal airfield, have become outdated and virtually useless. Whereas our Spitfires of the war could take off along grass, our defensive jet fighters of today need strong and lengthy runways. Not only for take-off, but for landing.

There have been a few attempts to reduce the landing speed of aeroplanes so that such long runways might not be necessary, but overall they have not amounted to much.

Now, in the fifty-first year of the aeroplane, a revolutionary change is taking place. Aeroplanes are being designed that will need no runway at all.

The helicopter has proved one way of rising straight off the ground, but the new designs now under development are for fixed-wing machines. Thus a beginning is being made with winged aircraft to return to the elementary take-off and landing of the balloon.

Work on such aircraft is going on both in this country and in the United States. It is believed that Russia also has not overlooked the idea of Vertical Take-Off.

British VTO research is a close secret, but its existence was disclosed in the House of Commons by the Minister of Supply, Mr. Duncan Sandys, on July 19. He said, in reply to a question: "The Ministry of Supply has given contracts to a number of firms to undertake research into various methods of vertical or near vertical take-off. Engines and airframes suitable for this purpose are being developed."

Answering a supplementary question, the Minister added, "I realise the importance of this work. Quite a lot of money has already been spent on it and the amounts being spent are going up fairly steeply. All this research into vertical and near-vertical take-off has very important military applications and, therefore, I do not want to go into details of exactly what we are doing and how far we have got."

Undoubtedly at this stage it is only the military application of VTO that is being studied. The straight upward-rising passenger aircraft is obviously many years distant, but if the principle is applied successfully to fighter aeroplanes it will be only a matter of time before the designers of airliners should be able to embody it in their plans. Details of two experimental Vertical Take-Off fighters for the United States Navy have been released. Both are completely revolutionary aeroplanes. One is the Lockheed XFV-1; the other the Convair XFY-1. Both are designed not only to take off vertically, standing on their tails so to speak, but to land straight down on an area the size of a tennis court. Both aircraft are powered by double Allison turbo-propeller engines linked to one shaft and driving contra-rotating propellers. The Lockheed has conventional-shape wings; the Convair is delta-winged.

FIG. 1. The Convair XFY-1 delta-wing fighter made its first free vertical take-off on August 1 this year.

Special mobile rigs have been designed to lift the aeroplanes on to their tails for take-off. In tethered tests inside a vast airship hangar in California, the eight-ton Convair has been 'flown' by test pilot J. F. Coleman to fifty or sixty feet and then descended gently back on to its tail, a cross-shaped affair consisting of the delta-wing tips and a double tail fin at right angles to the wings. Each aircraft has shock-absorbing struts on each of the four corners of its tail.

Lockheeds say that their aircraft is designed to fly—horizontally—at about 500 m.p.h. Mr. H. L. Hibbard,

engineering vice-president of the Lockheed concern says: "The XFV-1 points the way to the day when nearly all fighter planes will take off vertically. It will be a flying laboratory to prove and check a large number of new techniques and devices required for vertical take-off. The plane's twin-turbine power-plant will produce a thrust greater than the weight of the aircraft, thereby making vertical ascent possible and providing a remarkable rate of climb while rising to the levelling-off altitude."

New tilting seats in both aeroplanes keep the pilots in a semi-upright position during the vertical ascent. Though the experiments are in an early stage yet, Lockheeds have disclosed that the fighter is designed to "perform a number of varied but still secret missions, and carry various kinds of armament, including atomic weapons, from shipboard or shore bases". Landing is expected to provide the greatest difficulty. The plan is to swoop into a vertical position and then, while the aeroplane 'hangs' on its propellers, to drop gently down on to the tail.

Another U.S. aeroplane concern, the Bell Aircraft Corporation, is reported to be approaching the near-vertical take-off problem, using pure-jet engines instead of propeller-turbines. It is said that the Bell design employs tilting jet engines on the wing-tips, the powerful jet thrust giving a 70 degrees take-off. The engines return to the horizontal position for normal flying.

The idea of a direct jet thrust on to the ground is probably a natural follow-up to the propeller-driven vertical take-off. But it would seem that while it might be possible to design such an aeroplane, it would have to land in the conventional way, not having propellers on which it could 'hang' for a slow descent.

The advantages of a vertically rising fighter are many. The interceptor (which will have to be used for a few more years until the guided missile is perfected) could get off the ground more quickly; could operate regardless of air attack on runways; and could be called upon as a ground-attack aircraft from bases immediately behind the line. Each ship could carry its own defensive fighter in addition to having carrier protection.

COOKING BY THE SUN

In the arid or semi-arid regions, there are many areas where fuel for cooking presents a problem. There may be no extensive distribution system for electricity or gas; oil may be expensive because of the charges involved in transporting it. Wood fuel may be available, but it is not sound practice to cut down the trees for this purpose because they afford valuable shade. Animal dung is sometimes brought into service as a fuel, but this could be better used as manure to fertilise the land.

On the other hand, there is an abundance of sunshine in these areas, and therefore there is much to be said for the development of heating and cooking devices which utilise the plentiful supply of solar radiation. The possibility exists of using this radiation to heat houses.

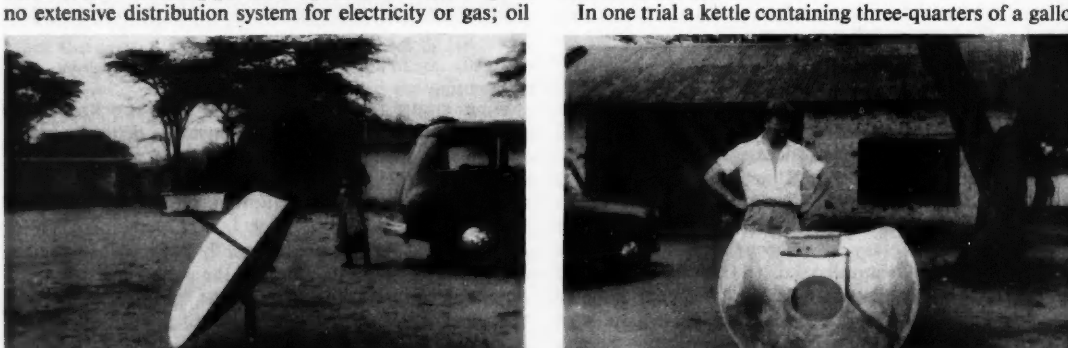
Neither of these techniques has been developed beyond the experimental stage, but a simple solar cooking apparatus (designed by the Indian Physical Laboratory) has been perfected which can be produced on the large scale wherever it is required.

A solar cooker suitable for use by dwellers in remote settlements and villages must conform to certain requirements; it must be small and light so that it can be easily transported; it must be simple to assemble and operate, and strong. Finally, it must be cheap. These requirements are met by the cooker developed by the Indian National Physical Laboratory (Figs. 2 and 3).

In this cooker, a cast-iron base plate carries the tubular main support, which can rotate through 180 degrees about its vertical axis. The top of the support has a ratchet face to which the cast-iron ring holding the reflector can be clamped by means of a locking handle. To the ring is bolted the aluminium reflector which can be tilted through about 60 degrees downwards from the horizontal position. The top of the reflector is cut away to allow closer approach to the cooking utensil. A stout iron rod holds a cooking stand consisting of a circular frame with wire mesh stretched across it. The angle between the stand and its support is adjustable so that the former can always be fixed horizontally. The diameter of the reflector is about 3 ft. 6 in. and of the stand about 1 ft.; other dimensions can be judged from Figs. 2 and 3. The reflected solar rays can be concentrated on an area, some 4 in. in diameter, at the centre of the stand.

Especially in the middle of the day and in the lower latitudes a cooker of this kind is effective. This was proved by a recent set of trials carried out under practical conditions in Somaliland.

In one trial a kettle containing three-quarters of a gallon



FIGS. 2–3. The solar cooker developed by the Indian National Physical Laboratory. These two photographs were taken during recent tests of the cooker in Somaliland.

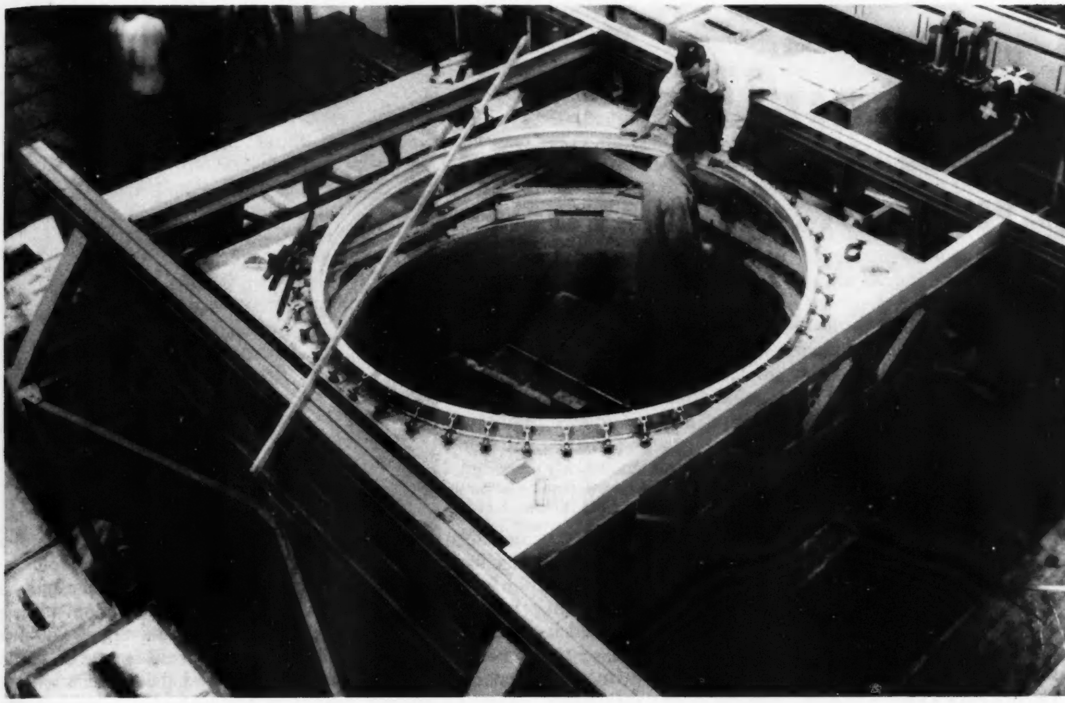


FIG. 4. DIMPLE, Britain's first heavy-water pile under construction at Harwell.

of water was boiled inside an hour from an initial temperature of 82° F. The altitude of the site was 5700 ft., so the boiling point was about 202° F. The amount of heat utilised in one hour was 900 B.Th.Us. The amount of heat arriving from the sun at the outer limit of the earth's atmosphere averages about 429 B.Th.Us. per square foot per hour. Of this amount of heat up to 360 B.Th.Us. may reach the earth's surface; it has been calculated that, at the time of this particular test, the figure was actually around 290 B.Th.Us. per square foot per hour. Taking the projected area of the reflector as 9·6 sq. ft., the energy available was 2817 B.Th.Us. Therefore the overall utilisation efficiency under these conditions was 32%.

It is probable that, for the most effective results, a pressure cooker should be used, in which case higher efficiencies could be achieved.

Certain precautions should be taken when using a solar cooker. To reduce heat losses the apparatus should be screened from the wind; the base of the cooking utensil should be blackened to limit reflection; the surface of the reflector should be kept clean and undamaged, and it should be correctly orientated and its angle of elevation frequently adjusted to follow the apparent movement of the sun.

It is generally agreed that, with reasonable care, this cooker is a device worth using in countries with a high daily sunshine average, and where normal fuels are difficult to obtain. Improved performance could, of course, be gained without loss of essential lightness and mobility by increasing the diameter of the reflector to something like 4 ft. 6 in.

BRITAIN'S FIRST HEAVY-WATER PILE

DIMPLE,* Britain's first heavy-water pile which has been built at the Atomic Energy Research Establishment, Harwell, is now in operation.

This is a low-powered thermal neutron research reactor. The heavy-water moderator is contained in a tank which is surrounded by a graphite neutron reflector. Outside this is a concrete radiation shield. The reactor fuel is submerged in the heavy water. Both the type of fuel and its arrangement in the tank can be changed quickly so that what is, in effect, a different design of reactor can be built up in a matter of a few days. The reactor will only be operated at very low power so that its structure does not become sufficiently radio-active to prevent the necessary handling.

The behaviour of the wide variety of design can, therefore, be investigated experimentally in a relatively short time.

The versatility of DIMPLE will make it an extremely valuable tool in the design of future power-producing reactors, and for measuring essential constants in reactor physics.

One of the first functions of DIMPLE will be to carry out experimental work for E.443, the new and more powerful heavy-water reactor which is under construction at Harwell and which will provide the high neutron flux essential for some research purposes.

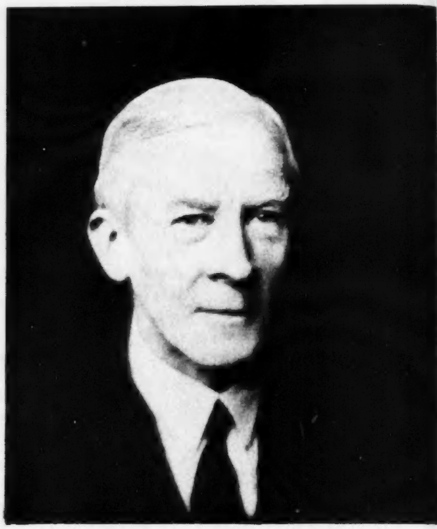
* The nickname 'DIMPLE' is based on the initials of the title Deuterium-Moderated Pile, Low Energy.

SCIENCE

AND HUMAN NATURE

DR. E. D. ADRIAN

O.M., P.R.S.



This week the British Association holds its 116th annual meeting in Oxford. The opening ceremony on September 1 was held in the Sheldonian Theatre, and the Vice-Chancellor of Oxford University conferred the honorary degree of Doctor of Science on Sir Ben Lockspeiser, Sir John Lennard-Jones, and Sir Harold Spencer Jones, the Astronomer Royal. Afterwards Dr. E. D. Adrian, O.M., P.R.S., delivered his presidential address, the full text of which is printed here.

Three hundred years ago a scientific society used to meet in Oxford every week in the rooms of Dr. Wilkins of Wadham College. It was the first of its kind in our country and it had what we should now call an escapist motive. Fifty years before Francis Bacon had published his great plan for a new road to knowledge, by concerted observation and experiment, and Harvey soon after had made the experiments which proved the circulation of the blood. But then the country had been torn by civil war. It had killed its king and could not see how to reach settled government. Dr. Wilkins had collected a band of scholars of inquiring mind, Boyle, Wren, Willis and others whose names are now part of the history of science, and they met together to take what comfort they could in the new kind of knowledge which could be confirmed by experiment instead of the appeal to authority. "The first purpose was no more than only the satisfaction of breathing a freer air and of conversing in quiet with one another without being engaged in the passions and madness of that dismal age."

So it was here that the scientific age was conceived in England, with the conflicting loyalties of the Commonwealth as a background, and I can admit Oxford's claim the more cheerfully because Dr. Wilkins moved to Cambridge and was for a short time Master of Trinity College, just before Isaac Newton came there as a young undergraduate.

When the King came to his own again the temper of opinion changed. There were great prospects ahead. The philosophers moved to London convinced that their inquiries would lead to material prosperity as well as to deeper knowledge. They founded The Royal Society and Isaac Newton's *Principia* established the mechanical order of the world. The material progress followed more slowly, but one hundred years after Newton's death it had already begun to affect the lives of half the people in this country. Scientists as usual were in no doubt about the value of what they were doing and they felt it was high time to share their faith and some of their responsibilities.

In 1831, therefore, the British Association was founded for the Advancement of Science, and at the annual meeting our leading scientists assembled in one big town after another to spread the news of this fresh source of knowledge and of material advance; and the Association has gone round ever since on much the same errand, announcing new discoveries and airing controversies before an audience which has grown steadily in size and in its understanding of what the scientists are about.

But now the products of science are everywhere. Knowledge of the material world is constantly growing and its consequences are of such spectacular nature that everyone is aware of them: few people now can doubt that the scientist's picture of the world must have some validity if it enables him to deliver such remarkable goods. So it has come about that the advancement of science is in everyone's mind. Why then are we here today? What is there left for the British Association to do if it can only preach to the converted?

THE B.A.'s IMPACT ON PUBLIC OPINION

For scientists it can do a great deal. We are all specialists nowadays and here we can learn what is happening in fields outside our own, but it is true that these meetings must lack some of the appeal they had when the whole territory of science was so much smaller. Progress is too rapid for the new discoveries to be saved up as a birthday present and controversies have become too technical to be aired in the market-place. Yet there is one very great and worthy task which needs the help of a body like ours which brings scientists and laymen together. The Association must show the layman where the scientific age is leading him. It is by its impact on public opinion that the success of these meetings must be judged.

No meeting of the Association at Oxford could pass without reference to that famous occasion when its impact on public opinion was highest, when it was made quite clear that the pursuit of natural science would mean a

painful revision of beliefs as well as a gain of material comfort, when it claimed acceptance for the theory that denied the special creation of mankind.

It was in 1860, the year after the publication of Darwin's book on *The Origin of Species*. Bishop Wilberforce was to speak and Huxley was Darwin's champion. The audience was too large for the lecture room and they moved to the long west room of the Museum, but the first paper was dull, it was on "The Intellectual Development of Europe considered with reference to the views of Mr. Darwin", and after an hour of it the audience was restless and wanted something more dramatic. They had it from the Bishop, who spoke with eloquence and wit against the idea that man and the monkey could have a common ancestor. He ended with an ill-conceived joke about Huxley's claim that he was descended from the apes, but he sat down to general acclamation and the fluttering handkerchiefs waved by the ladies. Huxley had a more harshly coloured picture to present, the aim of life was merely to go on living, the road to progress was by the slaughter of the weak and the survival of the strong and man was cousin to senseless brutes. The scientists were demanding that the search must go on, that the evidence must be followed wherever it led, but until then it had not led to anything quite so bleak.

All this was no doubt implicit in Huxley's speech, but the audience at the British Association is human and what really stirred them was Huxley's grand indignation at the idea of a bishop condescending to such a paltry joke on so high a theme. His scorn forced the excitement to such a pitch that one lady fainted and had to be carried out, and afterwards no one, not even Huxley, could remember exactly what he had said. It did not matter so much, for the chief issue was no longer the origin of species, but whether the Bishop had really been guilty of a breach of good manners. But the dispute had been on the scientific plane and the evidence could not be ruled out because it was unpalatable: within a few years the battle for Darwin's theory was won and it seemed that the discoveries of science had forced the human race to give up beliefs on which it had relied for centuries.

Naturally the change came gradually, bringing discord into a good many families where the rising generation were zealous converts to the new creed. But now the scars are mostly healed. Advancing understanding of what was really at stake has made it possible for both sides to keep their ideals. The theory of evolution has lost its power to arouse passionate resentment or passionate faith.

I have mentioned that meeting for two reasons: because it emphasised that man himself was part of the natural world and because it emphasised also his right, at all events his determination, to go on searching for knowledge, for without his curiosity he would be nothing.

We all know where our curiosity has now landed us; with advances in atomic physics which might be applied to devastate half the world, and if they were so applied would certainly make life in the other half extremely precarious. Our grandfathers here were faced with scientific discoveries which were no laughing matter, for to many of them they spelled the end of all worthy human aims, but we face discoveries which might spell the end of all human aims, worthy or not.

We can regret that atomic bombs are possible without regretting the discoveries that have led to them. Advances in natural science cannot avoid advancing the methods of warfare; they do so when they make armies more healthy as well as when they increase the power of their weapons. But although the strategists have to think mainly of immense explosions and great devastation, it would be a mistake to suppose that these are the only dangers. Even if we can survive, then we must face the possibility that repeated atomic explosions will lead to a degree of general radio-activity which no one can tolerate or escape.

The level would not rise rapidly and there is a large margin in hand, but the physicists can estimate the persistent contamination which must follow an atomic explosion of a given magnitude and the biologists can assign limits to the amount of contamination which could be let loose on the world without serious danger to every part of it. When atomic energy is used to supply power for industry the dangers of contamination are real enough, but due precautions can be taken to avoid them. In a major war they would soon be set aside. Powerful nations who think they could win quickly might accept the risk. A few hundred large bombs would not raise the level of radiation to the point where it would become a general danger, and no doubt a country of small area like ours could be reduced to ashes by a relatively small mass of explosion. Though the ashes would be deadly, the rest of the world might escape them. But a long war between powers well armed with bombs would certainly involve an order of radio-active contamination which would involve us all, victors as well as vanquished.

Arguments that war does not pay will not count much when ideals are threatened. It is true that a war which would probably end in wholesale destruction can appeal only to people who are desperate, but they can be made desperate, and that is the end we have to guard against. There are conceivable safeguards, of course, but controls and conventions are not foolproof, and in future, whenever the world is split into two opposing groups with large stores of atomic weapons, it must face this added risk of catastrophe.

Yet we have surely no right to feel that our predicament is much worse than that of earlier generations. Our grandfathers could do nothing to ward off the danger which seemed to face their cherished beliefs, but our fate is in our own hands. We are afraid, and rightly, because we cannot trust ourselves to act peaceably, because we know that unless we are ready to give up some of our old loyalties we may be forced into a fight which might end the human race. Our predicament is the inevitable result of our curiosity and of the physical nature of the world we live in, but if we can make our behaviour worthy of our increased knowledge we can live safely. The scientist, therefore, has a double responsibility. He must apply his science to learn as much as possible about the mental and physical causes which make us behave as we do, he must study human nature to prevent its failures; but he cannot wait for the discoveries which might make us act more wisely: he must take us as we are and make it his task at meetings like this to point

out that the human race cannot stand more than a few thousand large atomic explosions whether they hit their target or miss it. If we can make this known universally our Association will not have failed in its purpose.

It may be optimistic to think that our dangers would recede if we had a better understanding of human reactions; in fact, if we must continue to make war there is no kind of scientific investigation which might not be used to make it more effective and there can be no guarantee that discoveries in the field of human conduct would be harmless. A drug or a system of education which would make us all do as we are told, a method of producing radical conversion to a new system of belief, a knowledge of new ways of rousing patriotic ardour, all these might be used with consequences almost as grim as the general deterioration in a radio-active world. The psychiatrist who discovers a cure for paranoia may find that he has also revealed a convenient way of producing it.

Our novelists have made us aware of these dangers, but it is some comfort to feel that in this case the increased knowledge could be used for defence as well as attack. We can only be protected from radio-activity by living in caves on uncontaminated food and drink, but an increased knowledge of how the mind can be influenced could certainly forestall many of the influences which might be used to undermine our integrity.

FREUD AND PAVLOV

It is certainly true that discoveries relating to our own nature may mean a painful readjustment of our beliefs: that, however, is a fair price for increased understanding, and in fact our ideas about our own behaviour have already been assailed in such a way that further revelations are unlikely to shock us. There is a fairly close parallel between the impact of the theory of Natural Selection one hundred years ago and that of Freud's theories on our own generation. The British Association does not come into it, because Freud's evidence was all on the medical side, but his views made the same kind of attack on our pride and met with the same passionate resentment or approval. The theory of unconscious forces moulding our thoughts has certainly diminished our stature as intelligent beings; yet the parallel still holds, for again we have recovered our equanimity. We are reconciled to the unconscious, though we may not have digested all the elaborations of psychoanalytic theory. We are no doubt less sure of ourselves, inclined to spare the rod and to put nothing in its place, but, on the whole, Freud has left us with a better understanding of human conduct and we are not down-hearted at finding it less rational than we used to suppose.

Freud would have liked to build up a system based on the physiology of the brain, but he was soon too deeply committed to the psychological side. Pavlov's conception of human behaviour was based on brain physiology, and it was less disturbing because it did not go into such uncomfortable detail. It is now perhaps more disturbing than Freud's, because Pavlov's notion of the conditioned reflex has come to dominate one side of the world, but we must not think the less of it because it has been used to justify a political system foreign to ours. Pavlov and Freud were both scientists of surprising originality. They gave a new impetus to research on human activity, but the fields they explored are still waiting for the next advance to show how much they will yield.

The difficulty is that there are so many fields of inquiry to cover, each with its own limited range of facts and deductions. Freud studied dreams and neuroses and explained them as the product of repressed desires. Pavlov studied learning in animals and explained it in terms of conditioned reflexes, but physiologists ever since Galvani have studied the reactions of nerve fibres and nerve cells, the units of the nervous system, in the hope of explaining what they do in the terms of physics and chemistry. This approach at the lowest level can tell us little about the way in which units are organised, but when we keep to physical and chemical problems we are in the familiar territory of the exact sciences, we know how experiments should be conducted and there are great technical advances at our disposal. It is when we begin to think of organisms rather than molecules that we seem to part company with mechanism.

At this end of the scale, then, our actions are found to depend on the vast mass of cellular material which makes up the nervous system, receiving signals about the outside world from the sense organs and sending out signals to the muscles to produce the complex movements of intelligent behaviour. The nervous signals can be recorded and analysed because they are revealed by brief electrical effects and we are rapidly gaining a fairly clear picture of the energy transformations which make them possible (and incidentally we should never have gone so far if there had been no radio-active sodium and potassium for tracing ionic movements).

The sensory inflow brings information about the events taking place outside us and progress reports to show how successfully we are dealing with them; signals from the muscles are needed to adjust the simplest movements and we are handicapped if we cannot hear what we are saying and cannot watch our step. But the great central mass of nerve cells has to fabricate a radically different pattern of messages to send out to the muscles, and it is a pattern which depends on past as well as present information, on what happened to us a year ago as well as on what is happening now. Unfortunately, it is a great deal easier to study the immediate reactions of the nervous system than the more persistent changes which alter its habits and give us our memories. We know next to nothing about the plasticity which is the most important feature of the brain, and that is the next hurdle for the biophysicists and biochemists.

THE RESTLESS BRAIN

But we do know that the cells of the brain do not behave as passive agents for conducting and combining the signals that reach them. As long as we are awake many of them are in continuous rhythmic activity. The system has its own reserves of energy and is unstable, at all events it is so constituted that a slight disturbance of equilibrium will start up a cycle of discharge and recovery repeated many times a second and extended through much of its substance. It is no great surprise to find that we are driven to our daily activity by a cell system of this kind with energy

to be dissipated, but we are now learning something about the interplay of the different parts of the system. It is found, for instance, that a relatively small collection of cells at the base of the brain has a profound effect on the general level of activity, so that we are aroused when it is stimulated and fall into coma if it is injured. We can see too how the chief focus of disturbance shifts from one region of the cerebrum to another when we transfer our attention. In fact we are beginning to trace a closer connexion between what is going on in the different parts of the brain and what we happen to be doing from moment to moment. For what it is worth we can see a physical reason for our restless lives and our insatiable curiosity.

One may well feel that the most detailed knowledge of brain physiology will never help us much in our efforts to live peaceably, but it would be rash to prophesy. Certainly there are people now who lead more placid, if perhaps less useful, lives, because their anxieties have been diminished by leucotomy, an operation on the frontal lobes of the brain. And long before the advent of leucotomy we had become accustomed to adjusting the activity of our nervous system by chemical agents. Tea and coffee, alcohol and tobacco are the stimulants and sedatives of the pre-scientific age, and now, to quote the preacher, there is no end to the works of the apothecary, and we seem to be much less afraid of using the confections he gives us to take away our pains.

BEYOND PHYSIOLOGY

Only the writers of science fiction would suggest a future in which the problems of civilisation will be dealt with by tampering with the brains of some or all of mankind. It will help us a little to settle our differences if we have the means of ensuring a clear head and an even temper after a long journey and a resetting of the daily rhythm, but clearly we must look beyond physiology for an adequate picture of the human brain in action. Though it should start at the molecular or the cellular level, the evidence for it must include the activities of the finished product. We must find out what human behaviour is like before we try to explain how it is produced.

We do know, of course, an immense deal about human behaviour, from our own experience and from the accumulated wisdom of the past, but it is only in recent times that we have tried to check our knowledge by the methods of natural science. The development of physical science dates from the time when direct observation and experiment were accepted as better guides than the principles which had seemed self-evident to the philosophers and the schoolmen. They were wise enough but it was found that they could be mistaken. And so now we can look to the many branches of social science to make a dispassionate study of what actually happens in our society without regard to what might be expected to happen if we are to believe all we have been taught.

The picture of human behaviour which the social scientist has to draw is of a system in which the units are men and women rather than cells or molecules. It is true that one man behaves very differently from another—it is part of our political creed that they must be allowed, within limits, to differ as much as they like. But, although we can insist that the units are not all alike, the general principles which determine their behaviour ought to stand out when we deal with millions rather than individuals.

There is, in fact, one branch of social science which can adopt this plan without difficulty. This is the science of economics which considers only the human activities of producing and consuming and studies the way in which these activities are to be balanced. When the balance is lost, credit and currencies fail and we may blame the economists for the plight we are in, but the status of their science is unquestioned, and no one would dream of saying that our complex civilisation could have done as well without them.

It must be admitted, however, that the strength of economic theories rests very largely on the fact that they can be worked out with very little regard to human nature. Men must be assumed to be capable of trading with one another and they must have a variety of skills and needs and possessions, but that is all, or nearly all, that the economist has to consider. Few of the many branches of social science can proceed on such a simple basis, and it is because of this that the subject as a whole has still to win full recognition in the country where the science of economics is so firmly established.

Theories describing or explaining other kinds of social activity are nothing new, they existed long before the theories of economics; but the economists have had the figures to check their conclusions, and until recently the sociologists have had little but their own philosophy and their own reading of history. Even Durkheim, who broke away from the philosophic tradition, could only point the way to a truly objective study of human society. Now the position is quite different. A century and a half ago it had only just been decided that the population of this country was on the increase. Many had thought that might be so, but there were no figures to show whether they were right or wrong. Now there are all the modern techniques for fact-finding, the questionnaires, the punched cards, the sorting machines and the statistical methods. It is far easier now to deal with large groups and the psychologists have far more knowledge of the irrational factors which can sway the smaller groups as well as the family and the individual. The stage seems to be set for the new development and it might well be the most important scientific development of this century. Why are we still so reluctant to think well of it?

The answer, I suppose, is that we are not yet convinced that the kind of observations that the social scientist can make will be sufficiently objective and sufficiently precise. Those of us who work in laboratories have a far easier task in selecting what we should observe, yet we know how difficult it is for us to select and observe fairly. We have to school ourselves not to reject the exceptional result as worthless when it does not fit a cherished theory; we have to be continually aware of our own fallibility even though we have all the figures and controls to keep us straight. We are loth to believe that the social scientists are more open-minded than we are, and the material they have to deal with seems to need an almost superhuman open-mindedness combined with an almost superhuman power of selection, of seeing the wood as well as the trees in it.

We feel that we should be lost in such a wood where everyone must feel the bias of his own upbringing and social ties, where there is so much that cannot be measured and may or may not be relevant and where there is rarely any opportunity to check the conclusions by experiment.

Our distrust is probably intensified by the layman's tendency to speak of experiments in the social field as though they were comparable with the experiments which obey all the exacting rules of the laboratory. There we can at least hope to proceed by changing one factor at a time. The social scientist would be the last to cherish any such hope: his whole training warns him of the complexity of any situation where human beings are involved. But many people seem to think that if something in the social field is done in a new and usually more expensive way we have only to call it an experiment to justify the conclusions we wish to draw. Certainly we must try new methods and hope to find out why they succeed or fail, but although a new way to check juvenile delinquency or develop a housing estate may give the most favourable results, it is very seldom an experiment from which one can infer the precise factors that have made for its success. A change in the birth-rate, a wet summer or a newspaper campaign are the kind of disturbing elements which would be too obvious to mention were it not that everyone who has worked in a laboratory must be aware of having overlooked disturbing factors which should have been just as obvious. We were lucky if our control experiments saved us from exposing our folly, but controls are far easier in the laboratory than in the world outside.

THE VALUE OF SOCIAL INVESTIGATION

This is a minor grudge. If we harbour it we shall be visiting the sins of the enthusiast on the very people who exist to keep them in check, and we must surely welcome any new branch of study which tries to substitute the methods of natural science for unchecked speculation. It is very easy for us to forget our own rules when we allow our feelings to take charge, to say that a result was too obvious to be worth the proof if we happen to like it, and if we dislike it to say that statistics can be made to prove anything. Perhaps we have forgotten how much we distrusted some new development near to our own field of science because it was unfamiliar and because we thought its backers claimed too much for it. We ought to remember that the now flourishing science of biochemistry was once distrusted by chemists as well as physiologists. It is human nature for the guild of natural scientists to delay admitting a new member till he has paid his dues and satisfied the examiners of his competence in the craft.

At present there are many kinds of investigation grouped under the umbrella of social science: the groups seem to have little in common and few of them can put their results into figures, but I think all of us, scientists and laymen alike, are becoming more aware of the value of social investigation and of the degree of certainty it can bring. We may have distrusted the army psychologists who classed us by our aptitudes, we may have read the Kinsey report from unscientific motives and we may continue to allow the accident-prone to drive their cars. We can see none the less that there are facts to be found out about our usefulness in society, about our relations to one another and about the risks we take. We can see too that the search for these facts can be conducted on reasonably scientific lines. It is too early to be cautious in spending money on large-scale investigations. They are bound to be costly and those of the social scientist deserve not only the support of national and international funds. There is this kind of support for the subject already, but it is too important a plant to be left in the hot-house atmosphere of research institutes and Unesco teams. It deserves to be in full contact with all the conservative and academic people in universities, the lawyers and historians as well as the economists, biologists and statisticians. There must be more social scientists in our universities so that the rising generation can see what they are like.

I have put in this plea for a subject about which I know so little because it seems to be developing more rapidly in other countries, particularly in the United States. We are handicapped, no doubt, by smaller resources, and perhaps by the remains of a national temperament which has made us prefer to work by ourselves and not as members of a large team. We ought not to expect too much. Social scientists, like economists, may be able to foretell the consequences which are likely to follow in a particular situation, but the statesman who goes to consult them may come away with little to comfort him and may turn to the quack doctor in the next street. We may find out a great deal about the tensions which lead to war without seeing the way to keep ourselves clear of it.

But human beings, when we consider them as material for the biologist, are not to be thought of as incapable of improvement. Other kinds of animal have been found to possess unexpected power of communicating with one another, but we are the one kind endowed with a brain which gives us the power of communicating by putting our impressions into words and appreciating the meaning of the words we hear. Speech would be little use to us unless we could remember what it meant, but memory, the ability to learn, is a property of the simplest kinds of nervous system. We alone possess a nervous system which gives us the power to order our ideas in words. We alone have this way of thought which allows us to compare a new problem with an old one.

With this unique equipment for thinking and communicating, we can form our habits not only from what happens to us personally but from what happens to our fellows, and from what has happened to countless generations in the past. And although the storage capacity of a single human brain is limited we have learnt to make permanent records of what has occurred, in visible symbols, so that what cannot be remembered can be found in a book. In this scientific era our store of knowledge is growing so fast that we shall soon need new ways to keep it available. Books have done duty for a thousand years and we should be sorry to lose them, but we can change our habits rapidly and it is already old-fashioned to write a letter with a pen.

This increasing background of experience has meant that we are constantly acquiring new habits and new ways of thought. It does not take us very long to see the way round old quarrels. Darwin and Freud no longer trouble us. We are no doubt born with brains like those of our

remote ancestors and when we are grown up we have no more native intelligence than they had, but our brains must have been so modified by what we have learnt that they are physically and chemically different, better adapted for the complex social life of our time. We have more knowledge at our disposal. If all goes well with our training, the brains we have ought to be more civilised than those of our fathers and those of the next generation more civilised than ours.

I have claimed that the scientific investigation of mankind can help the process of civilisation by finding the weak points in our equipment and suggesting remedies, but these scientific activities will play only a limited part in the development of human society in the scientific age. The power we have acquired over the forces of nature has made it possible to increase our mental training as well as our standard of comfort. Of the two or three thousand million people in the world perhaps not more than five millions are receiving a full university training, though no doubt more are trained in a narrow technology. Yet the number has risen steeply in spite of wars, perhaps even because of them, and it continues to rise. In the United Kingdom we have 85,000 students at our universities, about 1 in 30 of the whole age-group, and that may be all we should contemplate with our present system. A few years ago, however, it was only 1 in 60, and there must be many parts of the world where the university, as we know it, is only now beginning to play its part in civilising the most intelligent citizens. This could never have happened without all the scientific inventions which have been blamed for our troubles, the improved transport, the cheap printing, the electricity and the internal combustion engine. And a university training would have been far less civilising if it had never left the old authoritarian pattern which roused Huxley to speak in Oxford nearly one hundred years ago.

University students, however intelligent, are not usually considered to be the most peaceful members of the community. They have been more welcome in small country towns than in the capitals, where they can join revolts against the government of the day, and they tend wherever they are to be critical of those in authority. Long may students remain so. If they were not, if they believed all they read in an officially inspired press, or even what they were taught by unrestrained professors of the greatest integrity, there would be little chance of their learning how to use their knowledge for solving the new problems of our time. The plodding methods of the laboratory and the card index must be there to check their enthusiasm and to show them how the problems have come about. Even if they get no help from that, it is something to know that there are many people in the world today with brains trained better to deal with their environment by learning how its problems have been dealt with in the past.

Our Association is concerned with the advance of natural science. It began when we had little control over the forces of nature and we have now so much that we might soon become able to destroy two-thirds of the world by pressing a button. Yet the control which has been achieved by science has made it possible for us to improve our own natures by more education in the arts of civilised life. We may perhaps improve ourselves more rapidly if we can gain more insight into human behaviour. That is something which the Association can encourage, but it is only a small part of what it must do. It must not cease to encourage every kind of scientific inquiry, for it is human nature to inquire, to learn by experience, and to profit by what it finds out.

ATOMIC APPOINTMENTS

The Atomic Energy Authority announces that W. R. J. Cook, chief of the Royal Naval Scientific Service, has been released from his present post to take up that of Deputy Director of the Atomic Weapons Research Establishment, Aldermaston, Berkshire, of which Sir William Penney is Director. Mr. Cook moves to his new post on September 1, but for a short period after that date he will continue to assist the Admiralty.

Mr. Cook, who is 49, was educated at Trowbridge High School and Bristol University, graduating there in applied mathematics. After obtaining his M.Sc. for research in theoretical physics, he joined the research department of Woolwich, where he remained from 1928 to 1938. He specialised in rocket research for a good many years, being superintendent of the Aberporth Projectile Development Establishment (1943–45) and then chief superintendent of the Guided Projectile Establishment (1946–47). In 1947 he joined the Admiralty as Director of Physical Research; in 1950 he became chief of the Royal Naval Scientific Service.

F. C. How has been appointed by the Lord President of the Council to be his secretary for Atomic Energy matters. Mr. How is 56. He was appointed under-secretary dealing with atomic energy, Ministry of Supply, in 1946 and remained there until the end of last year. Then he became undersecretary in the secretariat of the Department of Atomic Energy.

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J. C. Duckworth, aged 37, chief engineer of the Ferranti Laboratories at Wythenshawe, has been chosen by the British Electricity Authority to superintend the design, construction and operation of its nuclear power stations.

During the war Mr. Duckworth was in charge of the department responsible for designing ground radar equipment for the R.A.F. In 1946 he joined the Chalk River atomic energy project in Canada, and afterwards he transferred to Harwell. His B.E.A. post will carry a salary of £2500–£3000.

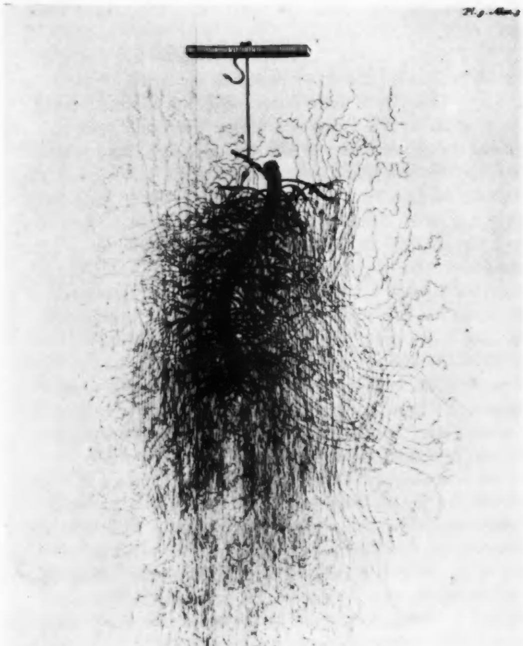

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FIG. 1. Many *Hydra* attached to piece of wood; engraving by Lyonet, from Trembley's *Mémoires*, 1744. FIG. 2. Groups of different corallines growing on shells; frontispiece to Ellis's *Essay*, 1755. FIG. 3. Hydroids of *Laomedea*; from G. Johnston's *History of British Zoophytes* (2nd edition, 1847). FIG. 4. Skeletons of the zoophyte, *Sertularia*; from Ellis's and Solander's book on zoophytes of 1786.

MEDUSAE AND ZOOPHYTES

PROF. C. M. YONGE
C.B.E., F.R.S.

One of the most surprising discoveries in the history of zoology was the discovery that there is a connexion between the small jellyfish or medusae and the hydroids which look so much like plants that the early naturalists called them 'zoophytes'—'animal-plants'. The details of the relationship between these two very different kinds of animal forms have taken many years to unravel. The latest addition to the literature of the subject is a superb monograph by F. S. Russell, F.R.S., on British medusae.

In this article, Prof. Yonge, who is Regius Professor of Zoology at Glasgow, discusses this new book against the general background of previous work on this group of British animals.

Since Aristotle first drew attention to the existence of many strange forms of life in the sea, knowledge concerning these has grown, at first very slowly and then with gathering speed—particularly after the establishment of the concept of species by Linnaeus in the 18th century. The progress of knowledge during the two succeeding centuries has been marked by the appearance from time to time of monographs dealing with different groups of animals or plants. In this country we are fortunate in the possession of a great series of monographs dealing with the animals and plants found in British seas. Many of the volumes published through the past century by the Ray Society deal with groups of marine animals. In addition many Victorian publishers, notably John Van Voorst, to whom British naturalists owe a great deal, were responsible for stimulating and often actively assisting the production of many important descriptive accounts of British animals and plants, both marine and terrestrial.

Although most fortunately the Ray Society continues year by year to issue new volumes on our fauna and flora, general interest in systematic zoology and botany has declined, while the cost of producing books demanding coloured illustrations continues to increase. Hence the unaided publisher is almost eliminated from this field, at least in Britain. It seems that only where the cost of production can be subsidised is it possible to produce monographs on the same scale as those published during the past century. Thus it comes about that admiration is mingled with surprise as one contemplates and handles the massive volume of *The Medusae of the British Isles** by F. S. Russell, F.R.S., director of the Plymouth Laboratory of the Marine Biological Association of the United Kingdom.

Within this book of over five hundred pages, which has 35 plates and 319 text figures, existing knowledge on these delightful inhabitants of our seas is brought together, and every known species is described and illustrated. This happy outcome of the labours over the past twenty years of Mr. F. S. Russell was made possible by the interest and generosity of the late Mr. E. T. Browne, himself a life-long worker on the medusae, with further financial assistance from the Royal Society and from the Syndics of the Cambridge University Press. The result is a matter of real pride to British marine biology and also to British publishing.

The small, indeed often extremely minute, jellyfish which constitute the medusae described by Mr. Russell are members of the great phylum known as the Coelenterata. These are all animals of essentially very simple structure but with a bewildering diversity of external appearance and habit of life and comprising many of the most successful of marine animals, such as the sea anemones, the stony corals and the soft corals, the sea fans and sea trees. The group also includes the small hydroids—all animals growing attached or at any rate of sessile habit like plants—in addition to the great jellyfishes and the delicate little medusae which move through the water by rhythmical contractions of the bell. To the individual coelenterate animals that are free-swimming like the common jellyfishes, the term *medusoids* is applied; the other kind of individuals cannot move freely in that way and are called *hydroids*.

In a group such as the sea anemones only the hydroid form is met with, while others consist only of active medusoids. In yet other groups within the Coelenterata a particular species possesses both types of individuals—that is, its life history includes both a hydroid form and a medusoid form. Thus it is that any modern study of the medusae must include some mention of the hydroids.

The hydroids form little plant-like growths (the term 'plant-like' is applicable because of the way the hydroids branch). They are often no more than one inch high, and they are found on rocks and on sea weeds particularly between tide marks. They are especially common in temperate seas, and so are abundant around British coasts. *Obelia* is a good example. To the hydroids is allied the little freshwater *Hydra*, although this does not form colonies as do most hydroids, nor does its delicate tubular body secrete an outer skeleton. The nature of the hydroids was long a mystery, and they were thought to be part animal and part plant—they have certainly much the same habit of growth as the latter—and were accordingly named *zoophytes*.

The minute medusae were for long overlooked, or perhaps regarded as no more than the young stages of the much larger and structurally more complex jellyfishes. When finally recognised as quite distinct from these, they were naturally thought to constitute a group of their own, and their connexion with the sessile zoophytes went unsuspected. The discovery first of the true nature of the zoophytes and second of the connexion between these and the medusae is well worth recalling, particularly where it represents the work of British zoologists.

TREMBLEY'S WORK ON HYDRA

We must begin, however, by referring to the work of the Swiss zoologist, Abraham Trembley. While living at the Hague, as tutor to the sons of Count Bentinck, he began

* Cambridge University Press, 1953, price £6 10*s.* 0*d.*

to study the little freshwater polyps which Linnaeus was later to name *Hydra*. In 1744 he published his *Mémoires, pour servir à l'histoire d'un genre de polypes d'eau douce, à bras en forme de cornes*. In this the elegance of his text is matched by the delicacy of drawings executed and etched by his friend, the no less distinguished zoologist, Pierre Lyonet. Trembley achieved international fame, and he was honoured by both the Royal Society of London and the Academy of Sciences at Paris. With the aid of a simple microscope this acute observer revealed that the so-called zoophyte was an animal which captured with its tentacles water fleas and then proceeded to engulf and digest them. For the first time he showed that animals may reproduce by budding, while with extraordinary manipulative skill he carried out pioneer experiments on regeneration and grafting.

ANIMALS, NOT PLANTS

The story now shifts to this country where the London merchant, John Ellis, first demonstrated beyond the possibility of further question the animal nature of the marine hydroid zoophytes. His interest in them began in a curious manner; one of his hobbies was the making of landscapes out of dried seaweeds and corallines, and some of these were shown by his friend Stephen Hales, the botanist, to the Princess of Wales, mother of George III. Royal interest prompted search for further specimens and also critical study of these. The great 17th-century naturalist, John Ray, had attributed all such attached growths, sponges as well as zoophytes, to the plant kingdom.

Starting himself with this assumption, Ellis soon found reason for doubt when he began to examine his zoophytes alive with the aid of a microscope. Eventually he relates how he "went to the Island of Sheppey, on the coast of Kent; and took with me Mr. Brooking, a celebrated Painter of Seapieces, to make proper Drawings for me. Here we had an Opportunity of seeing these disputed Beings called branched Corallines, alive in Sea-water, by the Help of a very commodious Microscope, of Mr. Cuff's the Optician in Fleet Street, which I had altered for that Purpose; and was fully convinced, that these apparent Plants were ramified Animals, in their proper Skins, not loco-motive, but fixed to the Shells of Oysters, Mussels, etc and to Fucus's." This statement was made by Ellis in his *Essay towards a Natural History of the Corallines, and other Marine Products of the like Kind, Commonly found on the Coasts of Great Britain and Ireland*. This finely illustrated book may be regarded as the first truly scientific study of a group of British marine invertebrate animals. In it Ellis establishes convincingly that zoophytes are animals. (Incidentally it was not until much later, in 1825, that Dr. R. E. Grant of Edinburgh showed that sponges also are animals.)

Amongst British zoologists, Ellis was succeeded in the study of the hydroids by Dr. George Johnston of Berwick-on-Tweed. The most representative naturalist of his day, Johnston lived a busy life as medical practitioner, and in his spare time concerned himself with the foundation (in 1831) of the Berwickshire Naturalists' Club, of which he was the first president; some fifteen years later he became president of the Ray Society.

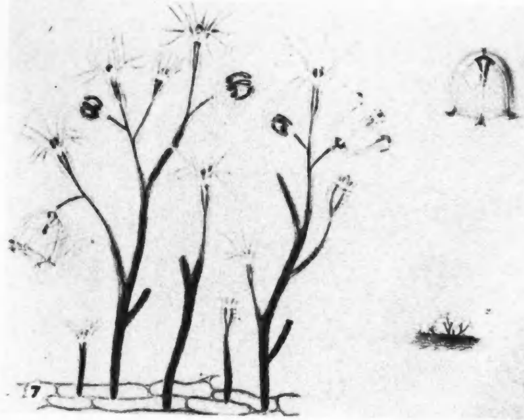
Johnston's interests were catholic, but in marine zoology he found his greatest satisfaction and he wrote books on conchology and on sponges as well as his two-volume *History of British Zoophytes*, first published in 1838. Johnston collected assiduously and corresponded with all who could help him with specimens and notes about distribution and habits. It is external appearance and nomenclature that are his main concern so as to fit his readers—soon to be increased in numbers by the many drawn to the study of seashore life by the writings of Philip Henry Gosse—for the identification of their specimens. He completed the work of Ellis and prepared the way for those who studied the structure of these animals and who revealed the connexion between zoophytes and medusae.

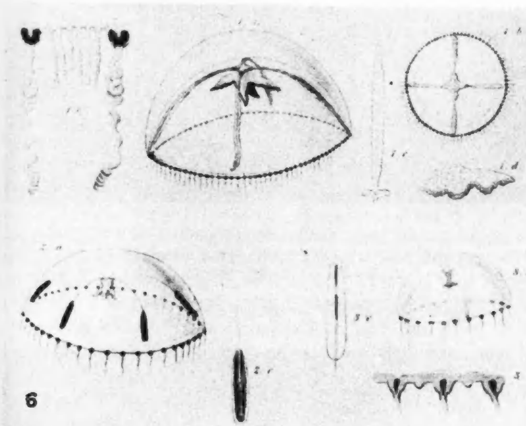
THE NORWEGIAN PASTOR'S DISCOVERY

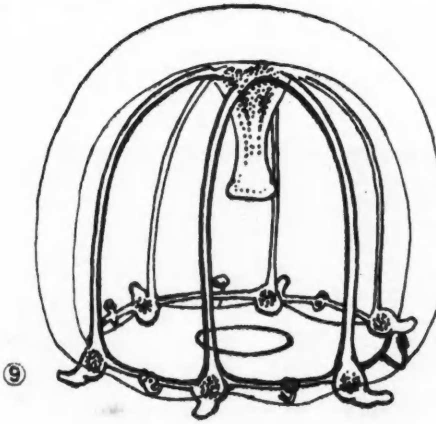
The first intimation that there might be both a hydroid and a medusoid stage in the same life history came from the work of the Norwegian pastor, later Professor of Zoology at Christiania (Oslo), Michael Sars. He found a small naked hydroid which he called *Scyphistoma*, and another which was subdivided by a series of transverse constrictions (so that it looked something like a pile of saucers), which he named *Strobila*. In 1835 he showed that the former organism gives rise to the latter, which then divides up producing little jellyfishes, each with eight lobes. Previously those tiny eight-lobed jellyfishes had been described as belonging to a separate genus called *Ephyra*. Finally he revealed how the *Ephyra* came to assume the appearance of the common jellyfish *Aurelia*. Thus he proved how four apparently different animals were but different stages in the life history of the one species.

It is no disparagement of Michael Sars, who was indeed a great zoologist, to attribute a little credit for this revolutionary discovery to Sir John Graham Dalyell, the most singular figure among a group of marine zoologists who resided in and around Edinburgh in the first half of the last century. A lawyer by profession, he studied the animals of the shores and waters of the Firth of Forth. He recorded his observations, illustrating them with fine coloured plates, in five impressive volumes, two comprising his *Rare and Remarkable Animals of Scotland*, the remainder being entitled *The Powers of the Creator Displayed in the Creation*. Independently of Sars, but published later owing to quarrels with the engraver of his plates, Dalyell described the *Hydra tuba*, as he termed what we now call the scyphistoma stage of *Aurelia*, giving rise by transverse constrictions into *Medusa bifida*, these being the ephyrae which grow into the adult jellyfish, called *Aurelia*.

About the same time that the large kinds of jellyfish were found by Sars to have this small hydroid or polyp stage in their life history, a similar state of affairs was found to exist in some hydroids. In a variety of cases medusoid bodies were found coming away from parent hydroids, but the observers differed widely in the interpretation of what they saw. Some thought these bodies were eggs, others that they resembled the gemmules produced by freshwater sponges; another explanation was that they were female polyps, or else buds liberated from the hydroid







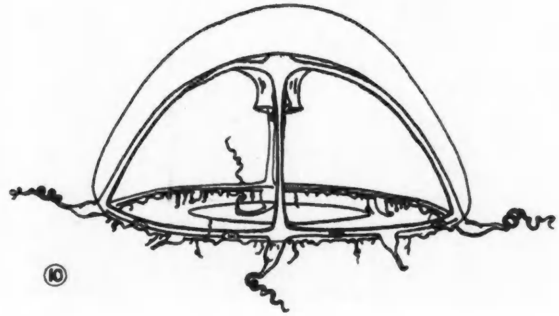
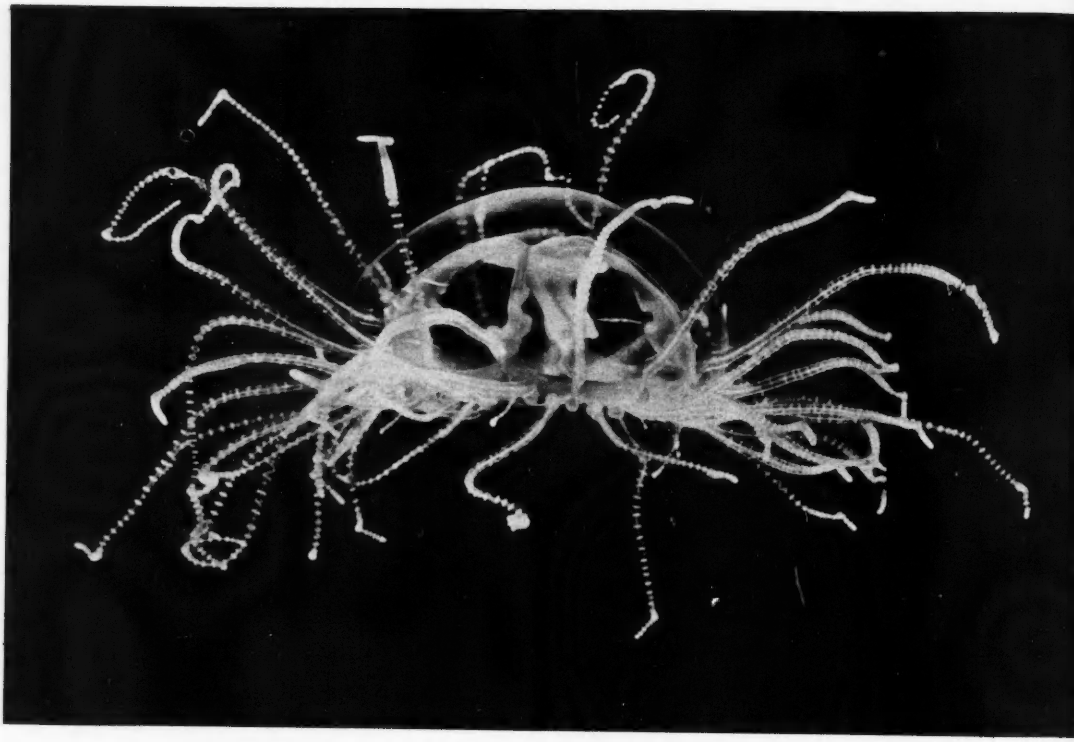
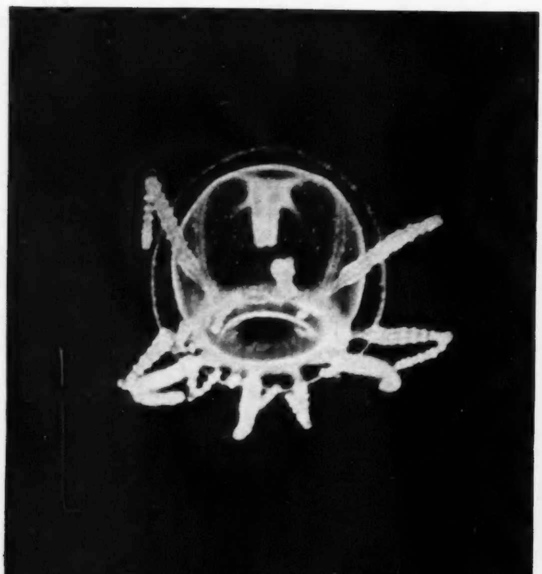


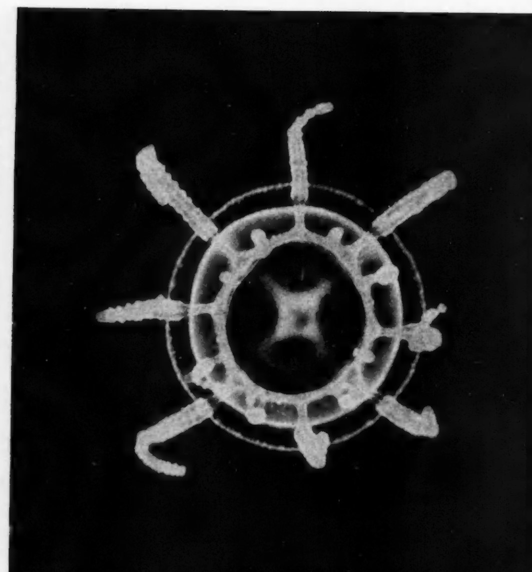
FIG. 5. *Hydra tuba*, dividing to form *Medusa bifida*; from Dalyell's ***Rare and Remarkable Animals of Scotland***, 1847. FIG. 6. Medusae of *Thaumantias*; from Forbes's *Monograph of the British Naked-Eyed Medusae*, 1848. FIG. 7. Hydroid and Medusoid of *Bougainvillea muscus*; from G. J. Allman's monograph of 1871. FIG. 8. *Lar sabellarum*; from Gosse's *Evenings at the Microscope*, 1859. FIG. 9. *Proboscidactyla stellata*, medusoid of "*Lar sabellarum*". FIG. 10. *Cosmetira pilosella*. A common medusoid recently associated with a hydroid named *Cuspidella*.



FIGS. 11–13. *Gonionemus murbachi*. The hydroid of this species has not been found. FIG. 11 (*above*). A mature medusa of *Gonionemus* reared by F. S. Russell in the Plymouth Laboratory of the Marine Biological Association. Lateral view, magnified 4 times. FIG. 12 (*bottom left*). Lateral view of young medusa; ×25. FIG. 13 (*bottom right*). Oral view of the young medusa of Fig. 12; ×30.

(*Photomicrographs by Dr. Douglas P. Wilson*)





which would themselves grow into hydroids. Finally, however, it became apparent that the medusoids possessed reproductive organs; they were, in fact, either male or female in sex; the eggs produced by the female medusoid were fertilised by sperm from the male medusoid, and then they proceeded to develop into freely swimming embryos, which eventually settled on the bottom where they gave rise to hydroids. Beginning as one feeding polyp, the hydroids proceed to grow by a process of repeated budding so that they eventually consist of many polyps attached to one another. But they never produce sexual organs, ovaries or testes. Eventually, however, all hydroid colonies produce medusoids, again by a process of budding. When these are almost fully formed the bell begins to pulsate so that, when the last fine connexion with the parent hydroid parts, the medusoids swim away, each one to become male or female as the case may be.

Such a sequence of events constituted—it was contended by the Danish zoologist, Steenstrup—an alternation of sexual and asexual generations, the sexual medusae giving rise to the hydroids, which formed medusae asexually by a process akin to budding. He thought alternation of generations was widespread in the animal kingdom, as it is in the plant kingdom. Most of his instances of alternation in animals have long ago been dismissed, but the life history of these coelenterates is still often described in terms of asexual hydroid alternating with sexual medusoid.

In point of fact the medusoid represents the adult, being sexually mature, the hydroid being a developmental stage and not a separate generation. But the position is complicated by the fact that in many instances the medusoid is not liberated as such but is retained on the hydroid. In some cases the medusoid is fully formed but never actually liberated, eggs or sperms being produced by it; in others it is reduced sometimes to such an extent that little evidence of its former existence remains apart from the presence of reproductive organs which now appear as though they had always been borne on the hydroid.

Up to this time medusae and hydroids had very naturally been regarded as totally distinct and classified separately. Thus Cuvier, the great French comparative anatomist, had associated all types of medusae with the larger and structurally more complex jellyfishes within one of the subsections of his Radiata, itself one of the four great groups into which he divided the animal kingdom. But now it became clear that the small medusae were intimately connected with the hydroid zoophytes, whereas they were only distantly related to the large jellyfish. The medusae were to form the subject of *A Monograph of the British Naked-Eyed Medusae* published by the Ray Society, in 1848. The author was Edward Forbes, probably the greatest of British marine biologists in the 19th century but fated to die at the early age of 39. He wrote of these animals as being "mostly minute, often microscopic. . . . They are active in their habits, graceful in their motions, gay in their colouring, delicate as the finest membrane, transparent as the purest crystal. . . . They have the power of emitting light, and when on a summer's evening the waves flash fire . . . it is to delicate and almost invisible Medusae that they chiefly owe their phosphorescence."

The fascinating problem now presented itself of linking each kind of free swimming medusa with its particular hydroid. Not all hydroids, as we have seen, do liberate medusoids; conversely some medusae (belonging to the orders known as Trachymedusae and Narcomedusae), have no hydroid stage, the fertilised eggs developing directly into medusae. But the great majority of medusae have a hydroid stage in development. Many zoologists attempted, by rearing hydroids until medusae were freed, to link together the two stages in the life history. The results of their labours were embodied in two books still of the greatest value. In 1868 Thomas Hincks published his two-volume *History of the British Hydroid Zoophytes*. This represented a major advance, for in the 21 years that had elapsed since the second edition of Johnston's *British Zoophytes* (1847) the number of known species had almost trebled and the detailed classification had greatly changed. Three years after Hincks's work came G. J. Allman's *Monograph of the Gymnoblastic or Tubularian Hydroids*, a larger work which was magnificently illustrated and published by the Ray Society.

One instance of the linking of hydroid and medusoid may be instanced. Philip Henry Gosse, who lived in Devon and gained particular fame as a worker on sea anemones, discovered in 1855 a grotesquely charming little hydroid that lives only around the mouths of the parchment-like tubes inhabited by the peacock-worm, *Sabella pavonina*. He describes the little hydroids as "having a most ludicrously-close resemblance to the human figure, and as closely imitating certain human motions . . . incessantly bowing and tossing their arms about in the most energetic manner". He gave it the name of *Lar* because, as he wrote, "it seems to require no very vivid fancy to imagine them so many guardian demons; and the Lares of the old Roman mythology occurring to memory, I described the form under the scientific appellation of *Lar sabellarum*". But ten years earlier a medusa eventually named *Proboscidactyla stellata* had been found by Edward Forbes and his friend M'Andrew near Oban. In 1872 Thomas Hincks observed at Ilfracombe a colony of Gosse's *Lar* with medusoid buds which looked very like the medusae discovered by Forbes and M'Andrew. Finally, near the end of the century, E. T. Browne described the entire life history and showed that hydroid and medusae were the same species, and Gosse's delightful name had to lapse in favour of that of the medusa.

Much similar work remains to be done, so much indeed that Mr. Russell finds it still necessary to classify the medusae separately, as did Forbes over a century ago. Nevertheless comparison of the two monographs reveals the great extent of added knowledge today while also emphasising how unexpectedly difficult it proves, even when medusae and hydroids are known to be associated, to connect each medusoid with its particular hydroid. The difficulty would seem to reside in the frequent small size and perhaps very transitory existence of the hydroid. Mr. Russell hopes in time to produce further additions to his monograph; each one will certainly reveal new advances in the linking of what were once considered the widely separated groups of medusae and zoophytes.

THE DIFFUSION CLOUD-CHAMBER

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The diffusion cloud-chamber is one of the atomic physicists' newest toys, and there are two good reasons why that description may be taken rather more literally than the same description applied to the latest cyclotron or atomic pile. One reason is that the new type of cloud-chamber can be made easily and cheaply: in its simplest form is well within the resources of a school laboratory. The other is that, once you have made it, the temptation is very great to play with it.

The famous Wilson expansion chamber, which is normally sensitive to atomic particles for only a fraction of a second at a time, often works with a flash and a bang, and so distracts the inexperienced observer that the tracks appear and vanish unnoticed. It is the great fascination of the new type of chamber that the tracks of atomic particles or cosmic rays appear before your eyes in an apparatus that is quietly and continuously ready to reveal them. It is probably by a comparison of the expansion and diffusion cloud-chamber that the nature and virtues of the latter can best be brought out.

The working of an ordinary expansion chamber is probably well known to many readers of DISCOVERY, and its tremendous importance to nuclear physics has been emphasised in these columns many times. The visible tracks are lines of droplets of water or alcohol ('the condensant') condensed upon the ions left in the wake of fast-moving charged particles. The condensation occurs when the ions are formed in an atmosphere supersaturated with the vapour of the condensant, but the degree of supersaturation must be just right. The appropriate amount is achieved by an accurately controlled fall in the temperature of the gas consequent upon a sudden expansion of the chamber volume. For an air-filled chamber that uses water as condensant and operating at an initial temperature of 18°C the fall in temperature is about 29°C. The amount of vapour present, which was just enough to saturate the space at the original temperature, is about six times as much as is needed for saturation at the final low temperature, i.e. there is six-fold supersaturation. Immediately after the expansion, heat begins to flow into the cold gas from the walls of the chamber and the cold and supersaturated condition is rapidly returned to normal. Conditions suited to good track formation last for about one-tenth of a second, a period which is called the sensitive time of the chamber. The expansion, normally produced by the movement of a rubber diaphragm, results in a turbulent motion of the gas and the temperature differences give rise to convection currents. The swirling of the gas must die down and the temperatures return to normal before another expansion can be made and this may require a time of the order of one minute. Thus a typical expansion chamber is sensitive for about one-tenth of a second in every minute. The obvious inefficiency of this led to many attempts to increase the sensitive time or to reduce the 'dead time' between expansions and some of these attempts met with success. For instance, expansion chambers with sensitive times up to one or two seconds have been made by Bearden and others, while on the other hand Gaerttner and Yeater have described a special 'fast re-cycling' chamber in which the time between expansions has been reduced to a few seconds.

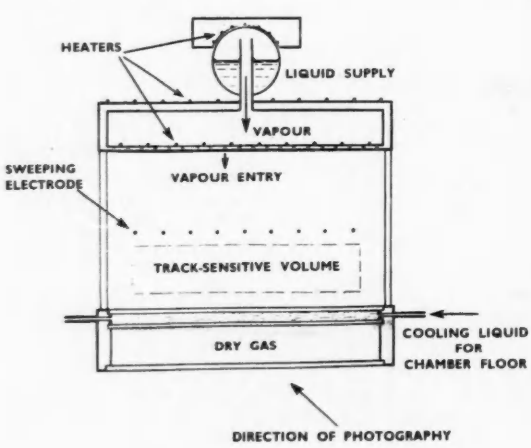

FIG. 1. A simplified diagram of the original diffusion chamber.

Nevertheless, the need for a chamber which would be *continuously* sensitive has long been felt. The first description of a working model based on the downward diffusion of the condensant vapour was published by Langsdorf in *Review of Scientific Instruments* (March 1939). The subsequent development during the nineteen-forties was in the direction of simplification of the original design but a trend of elaboration has now set in. Langsdorf's chamber is shown in Fig. 1, and the very simplest type of 'home-made' diffusion chamber in Fig. 4. Both exhibit the essential features of the construction. First there is a vessel to contain a volume of gas; then there is a source of warm vapour at the top; and finally a cold surface at the bottom. The warm vapour diffuses downwards reaching cooler and cooler layers of gas; near the bottom it condenses and collects on the floor. A region near the bottom contains gas supersaturated with vapour and here exist the conditions for track formation. When the temperature and vapour distributions have setted down to a steady state, tracks may be seen forming in the supersaturated or sensitive region and falling under gravity to the bottom. It may take half an hour to reach this condition during which, if the air is dusty, a dense cloud of droplets, with the dust particles as nuclei, will be seen to form and gradually settle out. By proper adjustment of the operating conditions the depth of the sensitive layer can be increased to several centimetres.

There are many variable quantities in the design and much of the experimental work on the diffusion chamber

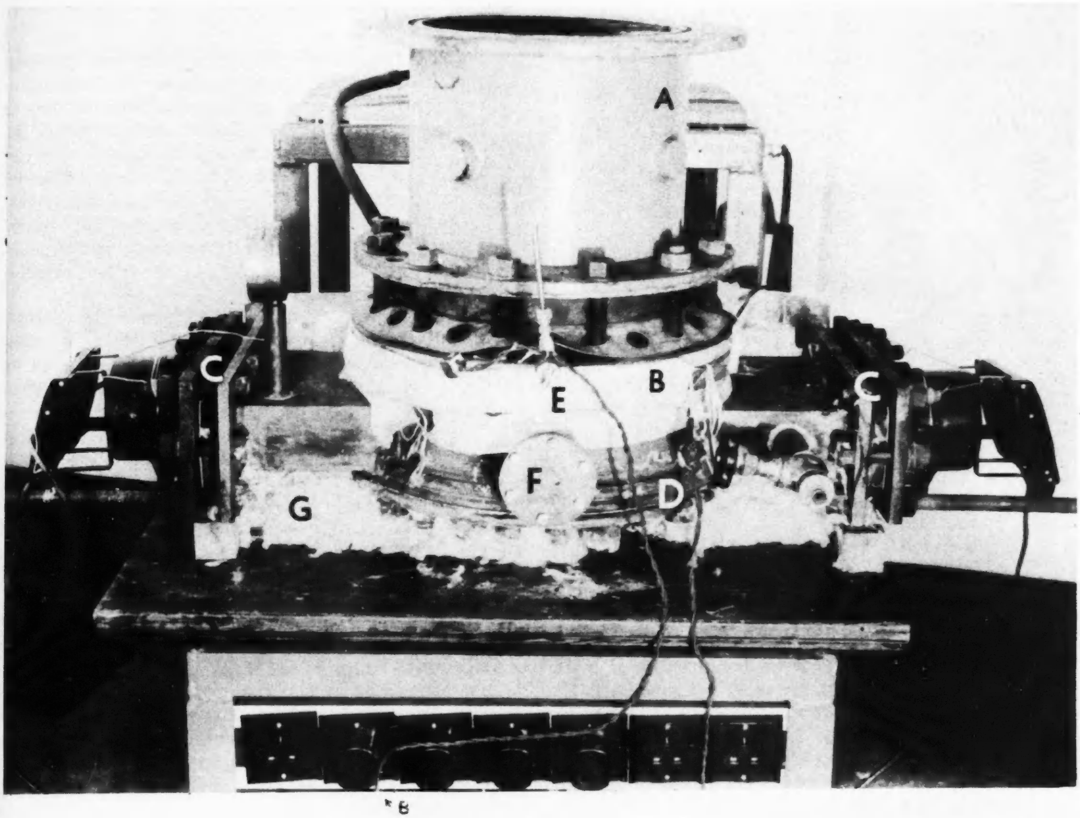

FIG. 2. A diffusion chamber recently built at Liverpool for use with the University's new particle accelerator. It can operate at pressures up to 30 atmospheres. The parts are:

A—Draught shield and camera support.
B—Heating tapes for top of chamber.
C—Entry ports for light beam.
D—Base cooling pipes.
E—Filling point for methyl alcohol.
F—Particle beam entry port.
G—Kapok lagging.

(By courtesy of Dr. W. H. Evans of Liverpool University.)

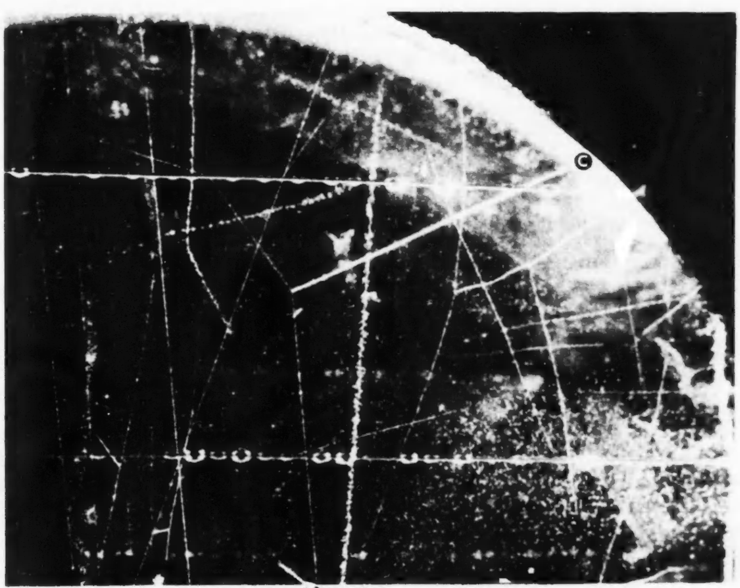

FIG. 3. This cloud-chamber photograph shows a negative pi-meson entering at *A*, striking a proton, and leaving at *B*. The recoil proton recoils towards *C*. The photograph represents part of the work of R. P. Shutt and his associates, and was provided by him. This particular experiment is referred to in the text.

has been devoted to finding how the operation is affected by increasing or reducing the gas pressure, changing the gas or vapour, and altering the temperatures or the chamber size. The many experiments, and also the theory of the instrument which R. P. Shutt published in 1951, show that a wide variety of conditions are compatible with track formation. The base temperature is usually maintained by solid carbon dioxide or 'dry-ice' at about $-70°C$, either by pressing a block of dry-ice against a metal baseplate or by cooling the base with a dry-ice-cooled fluid pumped round a closed system. To obtain a suitably high degree of supersaturation it is desirable that the base temperature should be below $-40°C$. A typical top temperature is $30°C$. It would take too long to enumerate all of the many conditions that have been tried but it may be mentioned briefly that successful operation has been achieved with air and most common gases at pressures above and below atmospheric, and with a number of condensing vapours. It is essential for the maintenance of stability of operation that the vapours should be light and the gas relatively heavy. The light vapour of methyl alcohol is often chosen for the condensant. The original Langsdorf construction has been modified by replacing the double glass floor with a brass baseplate; viewing and photography are then performed through a glass top-plate. The liquid supply may conveniently be held in a ring-shaped metal trough just below the top-plate and an electric heater is used to promote evaporation. Sometimes a velvet pad soaked in the condensant and warmed by radiation from a heater is used as the vapour source.

A number of additional features, common to both diffusion and expansion chambers, are necessary if useful photography is to be possible. Flash lamps of high intensity are preferable for illuminating the tracks at the instant of photography, though the tracks are easily visible to the naked eye with an ordinary bulb. An electric 'sweeping field' will also be necessary. The purpose of this is to

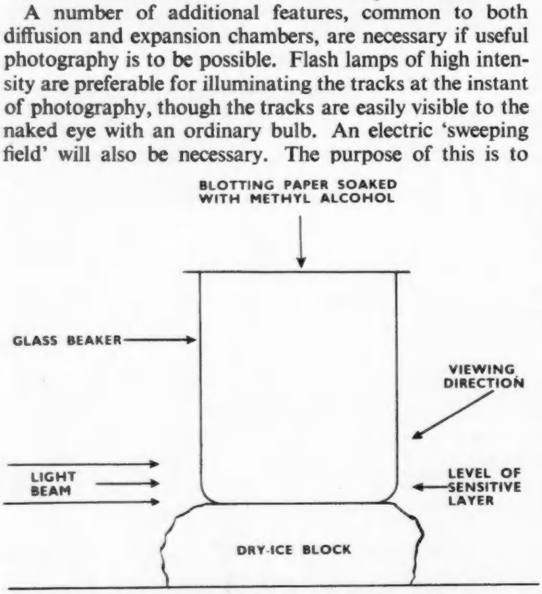

FIG. 4. A 'home-made' diffusion chamber. After ten minutes' operation, bright curly tracks and a few straight ones will be seen near the bottom against a continuous rain of droplets. These tracks are produced by cosmic rays and by radio-activity in the adjacent matter. The tracks are more easily seen if the bottom of the beaker is painted dull black on the inside.

remove from the chamber gas any ions left over from old tracks which may otherwise act as centres of condensation and cause droplet formation. This is desirable not only to prevent unwanted background droplets from confusing the pictures but also to avoid depleting the vapour supply in the sensitive region by allowing condensation on unwanted ions at the expense of the droplets in the desired tracks. The sweeping field will usually be switched off shortly before the photography so that the tracks themselves, consisting as they do of a double row of positive and negative ions, will not be pulled apart by it.

After this description we may now compare the qualities of the diffusion and expansion chambers. If, as we shall see, the diffusion chamber is not truly *continuous* in its sensitivity to tracks, it is at least much more nearly so than the expansion chamber. If one were interested in photographing radiations which were very feeble, so feeble indeed that there were rarely more than a few tracks visible at once, then the diffusion chamber might be called continuous and its working could be photographed with a ciné camera. This has actually been done, although continuous operation of the instrument in this way, with or without the sweeping field, does not lead to the production of the best tracks. In any case, an experiment may often require the injection into the chamber of more or less intense bursts of radiation from an accelerator or a radio-active source, and the large number of tracks will require so much vapour for condensation into their droplets that the supersaturation condition will be temporarily removed. The required concentration of vapour may need some seconds to build up again after the burst. Thus there is a 'dead time' with a diffusion chamber too, but it is considerably shorter than that of an expansion chamber of comparable size and gas pressure. The short dead time is a major advantage of the new chamber. A large accelerator may be very expensive to run and radio-active material may have a short lifetime, therefore particles from either of these sources are much more efficiently photographed by an apparatus that will take a picture every few seconds than one whose period is a minute or two.

Another important advantage of the diffusion chamber is the simplicity of construction, particularly the lack of moving parts such as diaphragms and valves. This is illustrated in Fig. 2 which shows a chamber designed for a gas filling at high pressure. An expansion chamber for similar conditions would be very much more complicated, and its moving parts would require involved electrical and mechanical arrangements for synchronising the operation of the chamber with the arrival of the particles. The diffusion chamber avoids this, though the taking of the photograph will still need careful timing. As it happens, however, there is one important field of research which cannot take advantage of this simplification of technique. The main application of chambers which expand rapidly immediately after the radiation arrives is to the investigation of cosmic rays. In this field it is normal for the expansion to be triggered by the passage of a charged particle through two or more rows of Geiger counters placed, as a rule, above and below the chamber. Such chambers are called 'counter-controlled'. There is no

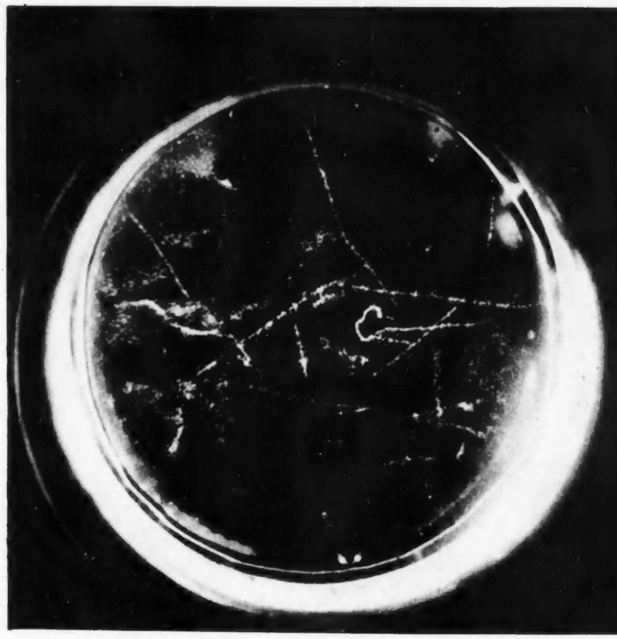

FIG. 5. This picture shows slow electron tracks produced by cosmic rays. This is the typical appearance of an air-filled diffusion chamber at one atmosphere pressure when no local sources of intense radiation are present.

expansion to be triggered in the diffusion chamber but there is no reason why the actual taking of the photograph should not be counter-controlled. Even so, the application to cosmic ray research would still encounter a serious stumbling block, namely, that the diffusion chamber operates *horizontally*, i.e. with the temperature gradient vertical and the sensitive layer parallel to the ground. On the other hand, cosmic rays arrive more or less vertically from above, and unless considerable trouble is expended, the sensitive region in the chamber will only be deep enough to show an inch or two of the track. This will usually be too little to be of much use, and it can be confidently expected that in the field of cosmic ray physics diffusion chambers will not become serious rivals to counter-controlled expansion chambers in the near future, if at all.

To continue the comparison, it may be said in the new chamber's favour that its gas, once it has reached its steady state and assuming the operating conditions are suitable and steady, is quite still, and the tracks are unlikely to be distorted by swirls and eddies as sometimes happens in expansion chambers. This is an advantage as regards track quality, but track quality is not only a question of distortion, for the width and sharpness of tracks are also involved, and the impression gained by the present writers from the many photographs in the literature and from their own experience is that the tracks in diffusion chambers are not generally of the highest quality judged by the standards of the expansion chamber. This may be due to the fact that the degree of supersaturation varies through the sensitive region and many tracks will form in places where the supersaturation is not as great as it would be in a well-adjusted expansion chamber. However, diffusion chamber technique is still comparatively undeveloped and will no doubt improve in the next few years.

It is only now that records of research carried out with such chambers, as opposed to articles on how to make and operate them, are beginning to appear. As an example, and to give some figures of actual operating conditions, some work by R. P. Shutt and his colleagues may be mentioned (Fig. 3).

They used a diffusion chamber in an investigation of the collisions of negative pi-mesons with protons. Protons, the targets in this collision process, are the nuclei of hydrogen atoms and for this experiment the chamber was filled with hydrogen to a pressure of 21 atmospheres. With the top of the chamber at 20°C and the bottom at −65°C and using methyl alcohol as the condensant, they produced a sensitive layer 6 cm. deep. About once in 5 secs. a burst of twenty mesons could be sent in, and between pulses the sweeping field was applied. 5600 pictures were taken on the first day. More details about this experiment can be found in *The Physical Review*, Vol. 84, page 1247.

To sum up, we may say that the ease and cheapness of construction and the near-continuity of operation are sufficient advantages to ensure a future for the diffusion chamber, especially in connexion with the many accelerating machines now in operation. As a simple and pleasing demonstration apparatus, it has already made its mark. At a time when improvements and developments are so often in the direction of increasing complexity, it is a pleasure to come across this striking example to the contrary.

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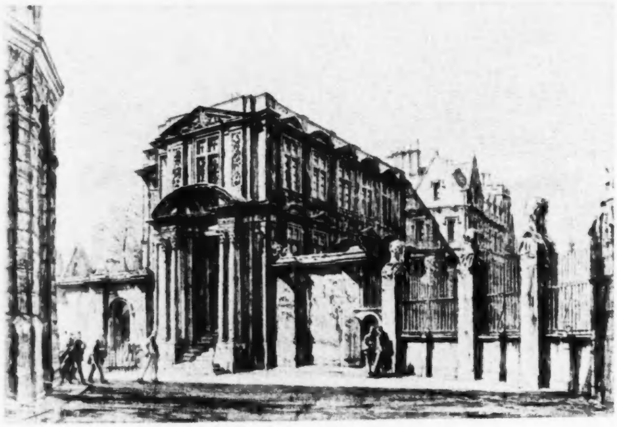


The original Ashmolean building in Broad St., which now houses the Museum of the History of Science.

SCIENCE IN OXFORD

by

WILLIAM E. DICK

Had Ford been in Nuffield's place making automobiles near Oxford instead of Detroit he would never have coined that fatuous aphorism, "History is bunk". For Oxford is instinct with history, and no visitor to this year's British Association meeting will leave the city without a clearer awareness that the roots of Oxford science go back very deep into the past.

Science without a sense of history is science without roots, and there can be no doubt that some knowledge of the history of science adds an extra dimension to this field of study as it does to all kinds of study. The western world finds itself today in much the same military position as did Christendom in Roger Bacon's time, and the threat of which Bacon was so acutely aware came from much the same geographical direction as it does today, an irony of history which illustrates how often progress leads men round in circles.

Anyone who knows the story of Roger Bacon will sense that he would probably have felt quite at home at a scientific conference such as the British Association, whereas it is doubtful whether a typical modern scientist would feel at home were he able to travel back in time and visit the Oxford of Bacon's period.

Roger Bacon, a Franciscan friar who worked in Oxford and in Paris, had empirical scientific method at his finger-tips. He was a student of Robert Grosseteste (1175?–1253), a man of mathematics and a man of science whose importance in the history of science is properly brought out in Dr. A. C. Crombie's *Robert Grosseteste and the Origins of Experimental Science* which Oxford University Press published only last year.

The ideas of both these remarkable men about experimental method were distinctly modern. Bacon in particular recognised that there were fundamental errors in the methods of the Scholastics, and indicted four of these—"dependence on authority, yielding to established custom, allowing weight to the general opinion and concealment of real ignorance with pretence of knowledge". Bacon was treated by the Church much in the same way that Galileo was later treated; the attempt was made to suppress his teachings, but the net result of all his enemies' efforts was that his ideas were never destroyed but only driven underground. They were transmitted by word of mouth, and some of his writings must certainly have been passed from hand to hand in monasteries where the liberal abbots 'winked at heresy'. His *Opus Majus* of 1267 was a plea for organised scientific investigation of natural phenomena which demonstrates just how advanced a thinker Roger Bacon was. Literature and legend credits him with many prophecies, as for instance the one about aerial cavalry, but perhaps his most remarkable prediction was the warning that intellectual stagnation must ensue if the Church did not assimilate the discoveries made by men of science. That stagnation materialised with all the inevitability of a Greek tragedy in the 14th and 15th centuries; the Scholastics marched to the end of their particular cul-de-sac, and the Church lost its spiritual and intellectual influence, which it has never since fully recovered.

The Scholastics seriously damaged scholarship, and the study of science suffered a severe check. Not until the 17th century did science in Oxford gain a new lease of life. The revival of Oxford science was impressive, and but for a concatenation of historical accidents it might have been more impressive still. According to Dr. John Wallis, one of the key men associated with the foundation of the Royal Society in 1662, it was during the Civil War that "divers worthy persons, inquisitive about natural philosophy" began to meet regularly in Oxford. At these meetings, which Dr. Wallis attended, they discussed "things pertaining to what hath been called the New Philosophy which from the times of Galileo at Florence, and Sir Francis Bacon in England, hath been much cultivated in Italy, France, Germany and other parts abroad, as well as with us in England". After Oxford had surrendered to Lord Fairfax in 1646, the city was a more peaceable place than London, and men of science who had been in the habit of meeting in London switched to Oxford. It has even been claimed that "the temporary repression of the forces of orthodoxy by the Parliament was not disadvantageous" to the new philosophers.

A leader of the group was Dr. John Wilkins, the new

warden of Wadham College. That college had been intensely Royalist, and its loyalty was severely punished by Parliament. The fellows and warden were expelled, and this was followed by the appointment to the wardenship of Dr. Wilkins, who was a brother-in-law of Cromwell.

Son of a Puritan goldsmith of Oxford, Wilkins was a remarkable man. Although his appointment aroused very mixed feelings at first, it was to bring "great fame and benefit" to the college. Though an essentially political appointee, he was well qualified to be warden; thus in one valuable account of this troubled period in Oxford history we read that "men of all opinions gladly met under his roof, and Cavalier parents did not fear to send their sons to Wadham". The 'invisible society' of philosophers, which was a direct precursor of the Royal Society, used to meet in the great room over the gateway of Wadham.

Other famous names which figured in the membership of that 'invisible society' were Thomas Willis, Ralph Bathurst, Dr. Seth Ward (who was something of a scientific 'Vicar of Bray'), Dr. Petty (later Sir William Petty), Thomas Millington (the Sedleian Professor of Natural Philosophy at Oxford, whom some regard as the discoverer of sexuality in plants). The younger generation was soon brought into contact with this group of philosophers; among the students who were associated with it were Sydenham, Christopher Wren and Robert Boyle. Boyle himself was not a member of the university, but he came to Oxford and settled there from 1654 to 1663 "in order to enjoy the company of the new philosophers". When Dr. Wilkins left Oxford to become president of Trinity College, Cambridge, the society used to meet in Boyle's lodgings near University College, where he had a laboratory and where he wrote several of his most important books (which were published by the university press). In one of his famous letters, Boyle wrote: "The best on't is that the corner-stones of the Invisible (or as they term themselves the Philosophical) college, do now and then honour me with their company, which makes me sorry for those pressing occasions that urge my departure . . . I will conclude their praises with the recital of their chiefest fault, which is very incident to almost all good things; and that is that there is not enough of them."

But this brilliant beginning was, as H. M. Vernon and K. Dorothea Vernon put it, "unfortunately destined to be only a false dawn for science in Oxford". After the Restoration, the philosophers took to holding their meetings in London, and the small and unofficial society was incorporated into the Royal Society. However, a branch of it did remain in Oxford until 1690, and it is recorded that sometimes it was so active as to arouse the jealousy of the Royal Society of London.

ANTIPATHY TO SCIENCE

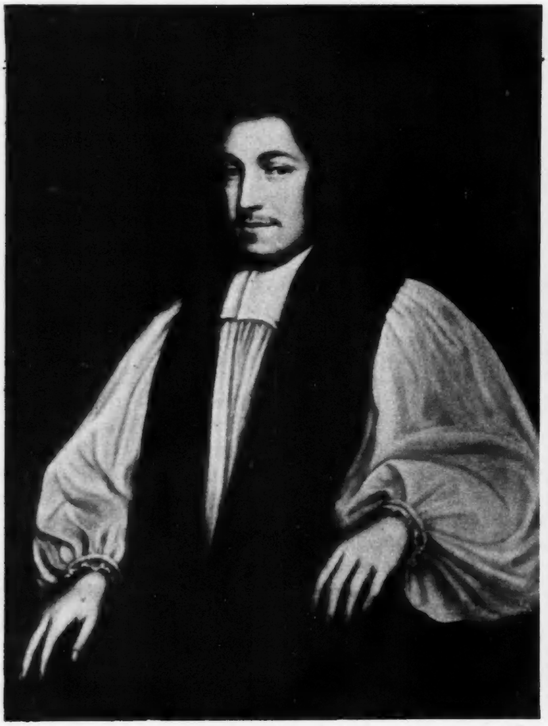
In 1683 a basement room in the newly-built Ashmolean Museum was equipped as a chemical 'elaboratory'; in this room some scholars "went a course of chemistry and held Friday afternoon conversations" with Bathurst and Wallis. Science was, however, scarcely a subject to be tolerated by the leaders of the university. A typical attitude was that expressed in the speech which the university orator made at the official opening of the Sheldonian Theatre (which was designed by a man of science, Christopher Wren); in his oration he attacked the Royal Society and declared that its members were "underminers of the University". (Small wonder that the author of the first history written of the Royal Society felt compelled to argue the case that "Experiments are not dangerous to the Universities".)

Certain scientific subjects had a foothold in the university. Henry VIII founded a professorship in Medicine and Anatomy; two medical lectureships were founded by Thomas Linacre (the founder of the Royal College of Physicians) in 1524, and assigned to Merton. That college came to be recognised as one of the main centres for scientific studies, and in 1619 we find that its warden, Sir Henry Savile, founded the chairs of Astronomy and Geometry which still bear his name. Charles I appointed William Harvey to the wardenship of Merton, but he had to leave Oxford only a year later when Fairfax's army approached the city so that he had little time in which to apply his knowledge to the benefit of medical studies in Oxford.

Botanical studies in Oxford came into existence mainly as a by-product of medicine. Those were the days when plants were the main source of drugs, and were studied as such. For that reason, the first botanical books were called *herbals*, and the first botanical gardens were called 'Physic Gardens'. Oxford's Physic Garden (now called the Botanic Garden) was founded in 1621 by Lord Danvers, later Earl of Danby. The site of this is five acres of riverside meadowland (which was originally the burial ground of the Jews of Oxford until their expulsion from the city in 1290) which is still leased by the university from Magdalen College, which lies on the opposite side of Bridge Street.

By 1648, over 1600 different kinds of plants were growing in the Physic Garden, which thrived under Jacob Bobart senior and junior in spite of the troubled times of the Protectorate and Restoration. The advantage of having a compact garden of this type, which is ideal for students who are liable to waste a great deal of time if they use a more comprehensive collection of plants, went unappreciated for many long years, perhaps because Oxford medical

The nucleus of the Ashmolean collection was 'Tradescant's Ark', bequeathed to Ashmole by John Tradescant jr. (*left*), whose portrait probably by Emanuel de Critz, can be seen in the picture collection in the Ashmolean Museum in Beaumont Street. (*Right*) Elias Ashmole, portrait by John Riley.



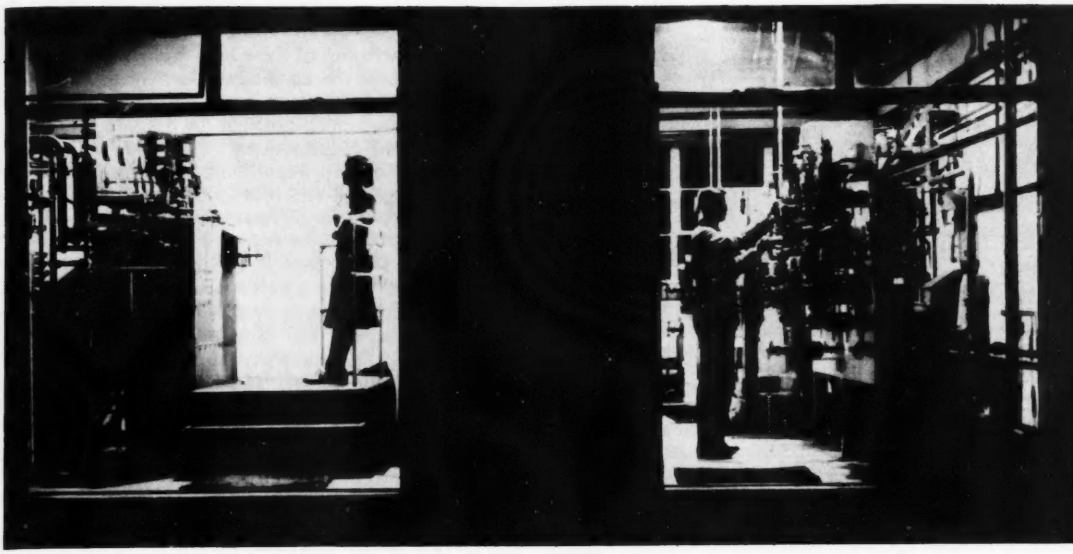
(*Left*) Dr. John Wilkins (1614–72), of whom the Dictionary of National Biography says, "he deserves, more than any other man, to be esteemed the founder of the Royal Society". By marriage to Robina French, he became in 1656 brother-in-law of Cromwell, who was Chancellor of Oxford University. In 1659 he resigned the wardenship of Wadham to become master of Trinity College, Cambridge. (*Right*) The Hon. Robert Boyle, who lived in Oxford from 1654 to 1663; his Oxford publications included *The Skeptical Chymist.*

students, like medical students everywhere, are inclined to regard compulsory botanical studies as irrelevant and as an imposition which they ought to be excused. There was unfortunately no proper professorship in botany until William Sherard founded the chair that carries his name. The first occupant of that chair was a German, J. J. Dillenius, a contemporary of Linnaeus; its present holder is Prof. C. D. Darlington. One of the famous names associated with the garden is that of G. D. Ehret; he was appointed gardener in charge in 1750 and later won a great reputation as a flower painter.

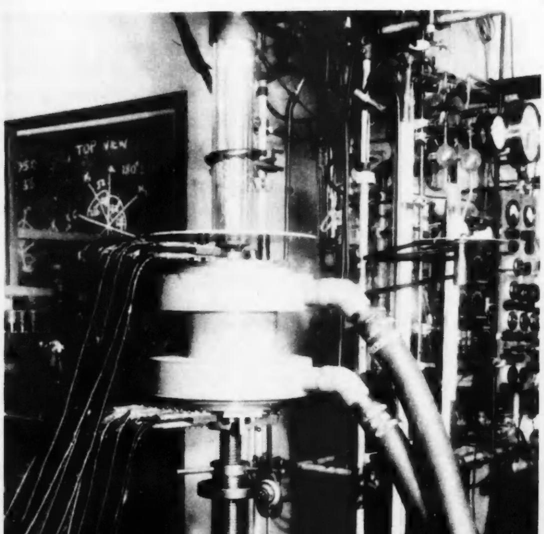
The creation of the Ashmolean Museum was a landmark in the history of Oxford science. Today the name suggests fine art perhaps rather than science, but in its origin it was a museum with particular emphasis on science. Elias Ashmole (1617–92), who was a lawyer with scientific hobbies, had acquired from John Tradescant jr. (1608–72) that remarkable collection of natural history objects which his contemporaries called 'Tradescant's Ark'. The contents of the 'Ark' were bequeathed to Ashmole, and to this valuable collection he added many items which he himself had collected. He offered the whole to the university in 1677 on condition that a building should be erected for its accommodation. The offer was accepted and so the Ashmolean Museum came into existence. Opened by the Duke of York (later James II) in 1683, this was the first public museum in England. Its original home was in Broad Street and now houses the Museum of the History of Science.

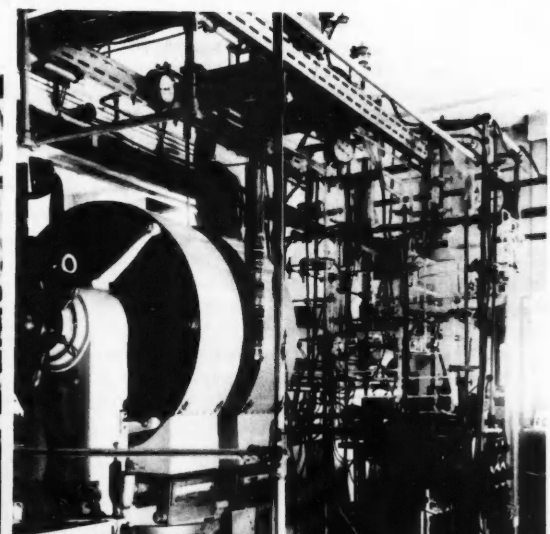
But the Ashmolean was much more than just a museum. In the words of C. H. Josten, it became "for more than a century and a half the centre of scientific life in Oxford". The Ashmolean collection was exhibited in the upper gallery of the building, while the ground floor contained the School of Natural History where scientific lectures were given by the curators and other famous men of science. The basement was occupied by a chemistry laboratory—the first chemistry laboratory ever created by the university—and by two important libraries, one containing chemistry books and the other covering natural history and philosophy. It was also the home of the Oxford Philosophical Society. The first keeper of the Ashmolean was Dr. Robert Plot, who wrote an early *Natural History of Oxfordshire*, which was published by the university press in 1677.

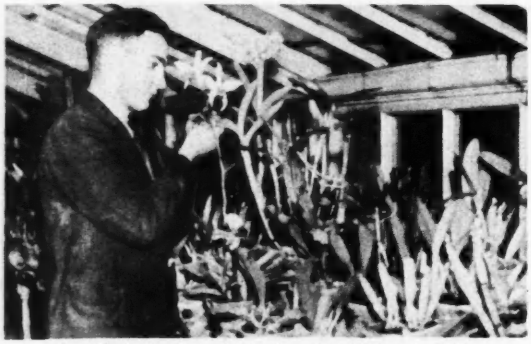
But once again Oxford was to see a decline in the standards of its scientific studies. Though the Ashmolean collection was added to, it was neglected and not until Dr. Thomas Beddoes took over in 1788 did things improve. Around the middle of the 18th century many of the



The Clarendon Laboratory, one of the oldest physics laboratories in Britain. These pictures, taken in the new building which was occupied in 1940, show some of the apparatus used in the low-temperature researches.
(*Above*) The hydrogen liquefier.
(*Bottom left*) Apparatus used for studying nuclear orientation, a field in which the Clarendon's nuclear physicists and the low-temperature department are collaborating.
(*Bottom right*) Apparatus for investigations in the temperature region below 1° Absolute.







Orchids in the Botanic Garden. Established in 1621, this is the oldest physic garden in England.
("*Oxford Mail*" *photograph*.)

exhibits in the Ashmolean were in a miserable state of decay and in 1755 the vice-chancellor ordered the burning of all its damaged specimens. Among them was the stuffed dodo which came from 'Tradescant's Ark', and this would have perished completely had not some intelligent assistant rescued its skull and claws, which can still be seen in Oxford and which constitute the only known remains of this extinct species of bird.

The decay in the Ashmolean was paralleled by the state of other scientific activities in Oxford. One reason for this sorry state of affairs was the practice of filling many of the scientific sinecures with eminent theologians who were quite unfitted for them. Another trouble was the fact that one individual could be given a plurality of posts. Thus we find that one man of science (Hornsby) could at one and the same time occupy the following five posts: Professorship of Astronomy; Readership in Experimental Philosophy; Sedleian Professorship of Natural Philosophy; Radcliffe Observer (i.e. he was in charge of the Radcliffe Observatory); Radcliffe Librarian.

In the early years of the 19th century Oxford scientific studies in general had reached a nadir. Thus, in medicine, so few students were graduating that it looked as though doctors to staff the Radcliffe Infirmary would have to be 'imported' from outside Oxford University. (In 1837 the doctors of England included only a hundred men who had graduated at either Oxford or Cambridge, which needed to learn a lesson from Scotland before matters were rectified.)

The attendances at scientific lectures were falling off seriously, as the following figures (which were originally collected by Dr. C. G. Daubeny) show:

	before 1828	*after* 1828
Chemistry	28	14
Anatomy	29	17
Experimental Philosophy	42	10
Geology	50	30
Mineralogy	50	15

Five men were chiefly responsible for the revival of Oxford science in the 19th century, and another factor to be taken into account when distributing credit for that recovery was the valuable public relations work done by the British Association for the Advancement of Science. The five men were Kidd, Daubeny, Buckland, Rigaud—and Acland. There is unfortunately no room here to give details of the activities of these men, but all of them contributed much to the campaign which finally won the sciences their rightful place in the university and which ended with it becoming possible for a student to study scientific subjects exclusively and be granted an honours degree at the end. (Anyone who wishes to read the details of this campaign will find it described most effectively in *A History of the Oxford Museum* by H. M. Vernon and K. D. Vernon, Clarendon Press, 1909.)

Not only did Sir Henry Acland play a key role in the campaign to persuade the university to establish an honours school in science (which came into being in 1850), but he was also the leader of the movement which culminated in the erection of the University Museum as a centre for organised scientific studies. This was started in 1855 on a site bounded on the west and the south by what are now Parks Road and South Parks Road. To quote the British Association handbook for 1954 (which is entitled *The Oxford Region: A Scientific and Historical Survey*, 214 pages with 63 maps and diagrams, and is published by the Clarendon Press, price one guinea), "this was designed to house the scientific collections of the University and to provide accommodation for the departments of Astronomy, Geometry, Experimental Physics, Chemistry, Mineralogy, Geology, Zoology, Anatomy, Physiology, and Medicine, and was sufficiently completed to be occupied by the various professors in 1858." Architecturally the Oxford Museum has always attracted interest, being a remarkable example of the revival of Gothic style. (John Ruskin, for instance, was always most enthusiastic about it, and indeed he and Acland wrote an interesting book about the Museum which was published in 1859, just before the building was finished.) In 1860 the British Association used the building for its third Oxford meeting; today one can look at a plaque in the wall of the west upper corridor which marks the scene of the dispute about evolution between Bishop Wilberforce and Huxley.

The Clarendon Laboratory, which was built in 1872 within the 'Science Area' that is centred on the Oxford Museum, is one of the oldest physics laboratories in England. The new Clarendon building was occupied as recently as 1940. The Science Area contains many other world-famous laboratories, as for instance the Dyson Perrin Laboratory with its fine reputation for research in organic chemistry. The work of Chain and Florey on penicillin was done within the walls of the Sir William Dunn Laboratory, opened in 1927 and standing on the eastern edge of the Science Area. Within this area one also finds the Radcliffe Science Library, which is in effect the science section of the Bodleian Library, one of the oldest and finest libraries in the world. Other details of the expansion of scientific activities in Oxford in the past hundred years can be found in this year's British Association handbook and in the standard *Oxford University Handbook*. The growth of Oxford University, whose origins can be traced back to the 12th century, is described in detail in the latest volume of the Victoria County Histories entitled *Oxfordshire, Vol. III. The University and Colleges of Oxford.*

SELF-FERTILITY IN FRUIT TREES

How it has been produced and its advantages

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It is still possible to find old farm orchards in which there are as many different varieties as there are trees. The names of these varieties have an old-fashioned flavour such as Forge, Curltail or Costard, but many are unnamed indicating that they have probably been grown from a pip instead of being budded or grafted. In contrast to this natural if inefficient cultivation which was prevalent 100 years ago we now have the serried ranks of artificial cordons. The immense advantages of modern fruit growing with its large orchards and limited number of varieties has, however, not been obtained without attendant troubles. The three most important have been: (i) the increase in pests and diseases, a problem which has been only partly solved by the ever-rising spiral of the spray programme; (ii) the need for reliable root-stocks (these have been provided by the East Malling Research Station); (iii) the provision of effective pollination. The last of these practical problems underlies the present experiments which have led to the production of self-fertile seedlings, which may eventually take the place of the existing self-sterile varieties.

Massed fruit growing began about 1860 with the rise of steam transport, but the fact that all varieties of cherries and most varieties of apples, pears and plums do not set fruit unless they are pollinated with pollen from another variety was not recognised even by 1876. For Charles Darwin in his book *Cross and Self-fertilization of Plants* described all the self-sterile plants known to him, with no mention of fruit trees. Darwin, who cast his net for facts extremely widely and was in close contact with notable horticulturalists and botanists such as Sir Joseph Hooker, would undoubtedly have been aware of any knowledge on a subject of such great interest to him. The first records of self-sterility in fruit trees was published in the U.S.A. by Waite in 1894, and this inquiry arose from the new practice of planting large blocks of grafted material of one variety, for in the old farm orchards with their profusion of named and unnamed varieties there would be ample provision for effective cross-pollination. Work on the problem was initiated in England by Backhouse at the John Innes Horticultural Institution in 1910, the year of its foundation. The problem was taken over by Crane in 1912.

It is owing to this work that we now have such detailed knowledge of self-sterility in fruit trees. The genetical interpretation of the results, however, was due to work on an annual species of tobacco by East in the U.S.A. We shall see again later how this type of pilot experiment in a quick-maturing plant can give the inspiration and confidence to tackle a problem which is both difficult and lengthy in slow-maturing fruit trees.

HOW SELF-STERILITY WORKS

Self-sterility is caused by an inhibition of the pollen tubes in certain types of styles: they are unable to penetrate to the ovary and thus fail to produce seed or fruit. The genetical control of this pollen tube inhibition is by a single gene which has a large number of different variants or alleles as they are called. This allelic series is usually represented as S_1, S_2, $S_3 \ldots S_n$. The styles, being somatic tissue, have two alleles because they have two sets of chromosomes, but the pollen grains have only one allele because they have only one set of chromosomes.

A pollen grain is inhibited only in a style carrying the same allele. Thus all plants are self-sterile, and different plants that have the same pair of alleles are cross-sterile. Only plants which differ in at least one allele are cross-fertile.

The action of this system is shown in Fig. 1.

How does this scheme apply to fruit trees? When varieties of sweet cherries, *Prunus avium*, are tested against one another in cross-pollination they fall into a number of groups. All varieties within any one group are mutually cross-sterile, but are cross-fertile with varieties in any other group. This is because all varieties in any one group have the same pair of **S** alleles, but different groups differ in at least one allele. These groups in cherries are shown in Fig. 2.

Similar groups are found in apples, pears and plums. For practical fruit growing it is essential to interplant varieties which belong to different groups and also which flower at the same time.

The **S** gene operates by producing specific proteins in the pollen and corresponding substances—probably proteins—in the style. Each **S** allele produces a protein of different specificity. Pollen and stylar substances having the same specificity react together like an antigen with its corresponding antibody. When they react they inhibit the growth of the pollen tube. This positive type of gene

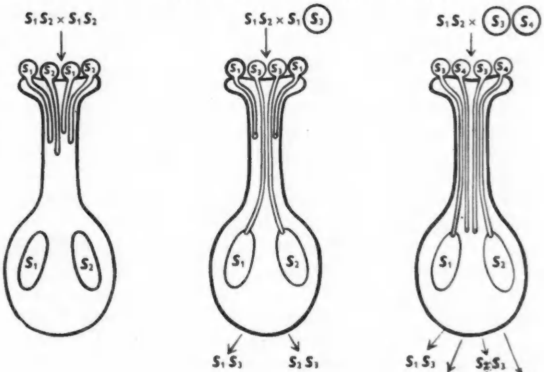


FIG. 1. Diagram showing styles and pollen; on the left is an incompatible pollination, the other two are compatible; centre, half the pollen is compatible giving two groups in the progeny: right, all the pollen is compatible giving four groups in the progeny.

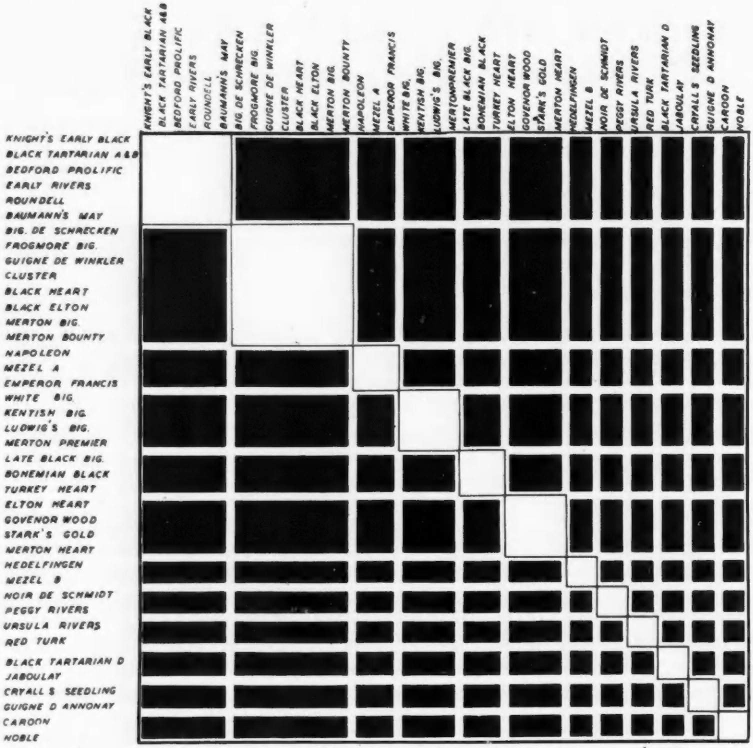


FIG. 2. Sweet cherry varieties grouped according to their incompatibility reactions; at the side of the diagram the female parents are shown, above are the male; white square = all cross incompatible: black = compatible.

action gives us the clue to a possible means of breaking down the system and producing self-fertile plants.

BREAKING DOWN SELF-STERILITY

Ever since H. J. Muller showed in 1928 that X-rays induce gene mutations, it has been realised more and more that the mutations produced are ones showing a loss or reduction in activity. Thus, if we can make the **S** gene mutate so that it does not manufacture its products, then a plant carrying this gene should be self-fertile.

The main difficulty with mutation work is that mutations, even after X-ray treatment, are very rare events, and unless there is a sieve for separating them at the source from the normal, the labour and space required to handle sufficient plants makes the task impracticable. It would mean growing and testing hundreds of millions of plants. Fortunately with self-sterility, as will be seen, there is such a sieve.

Pilot experiments were begun on a quick-maturing species of Evening Primrose, *Oenothera organensis*, which was known to have the same type of self-sterility as the tobacco plants and fruit trees.

Shoots with young flower buds were treated with X-rays and the pollen from these buds was applied to a large number of flowers of the same individual. It was found that there were approximately five thousand pollen grains on each stigma, which means a million on two hundred flowers pollinated. The vast majority of the grains fail to grow down the styles, but one containing a mutated **S** gene grows down and gives a seed (Fig. 3).

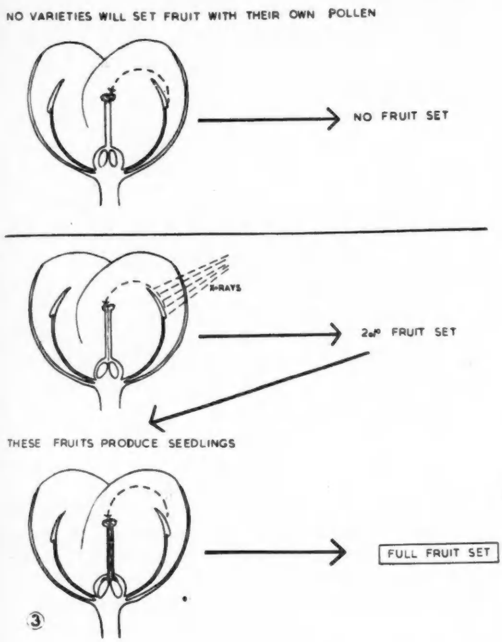
Thus X-irradiation gives us the means to damage the **S** gene and the stylar sieve of self-pollination gives the means of selecting out of millions the few that have been damaged.

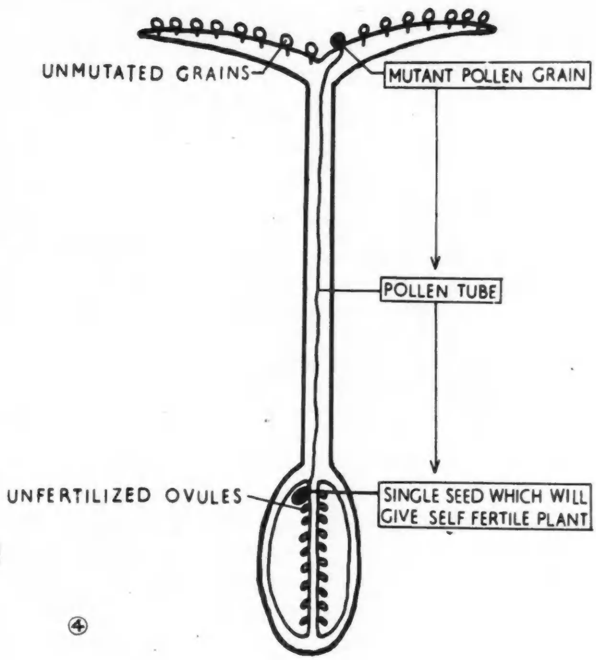
It was found, as expected, that many of the seedlings obtained after X-rays and self-pollination were fully self-fertile.

Work was begun along similar lines in fruit trees—sweet cherries, apples and pears. Sweet cherries were chosen for the main work because their self-fertility system is known in more detail than in other tree fruits and because all varieties are highly self-sterile. Trees of varieties like Bigarreau Napoleon, Emperor Francis, etc., were irradiated in February, and the pollen was used extensively on other trees of the same variety. Seedlings were obtained which flowered and fruited six years later, and, as expected, some of these were fully self-fertile.

The method of obtaining these self-fertile seedlings is illustrated in Fig. 4.

Apart from one of these self-fertile seedlings which is extremely early and of good size and flavour, the others are not outstanding in quality. But it should be remembered that when cherry seedlings are raised by the normal method of crossing between good varieties only about 1 in 200 seedlings has good commercial qualities. The next step has been therefore to cross the self-fertile seedlings on to good varieties and raise large families from which to select seedlings with desirable qualities. It is known from tests in the Evening Primrose that in some of these crosses all the progeny, and in others a half of the progeny, are self-fertile. The scheme which has been followed for raising these families is outlined in Fig. 5.





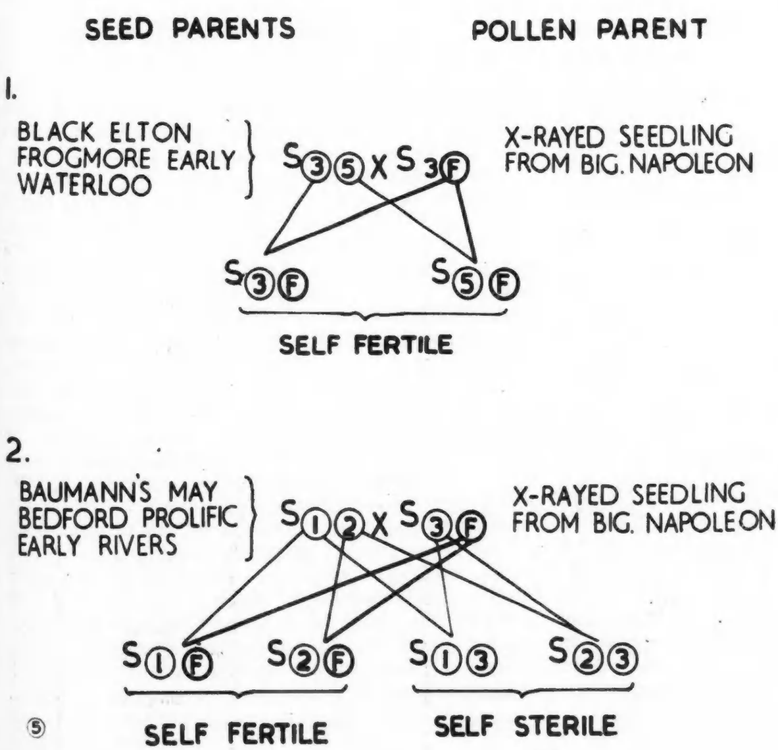
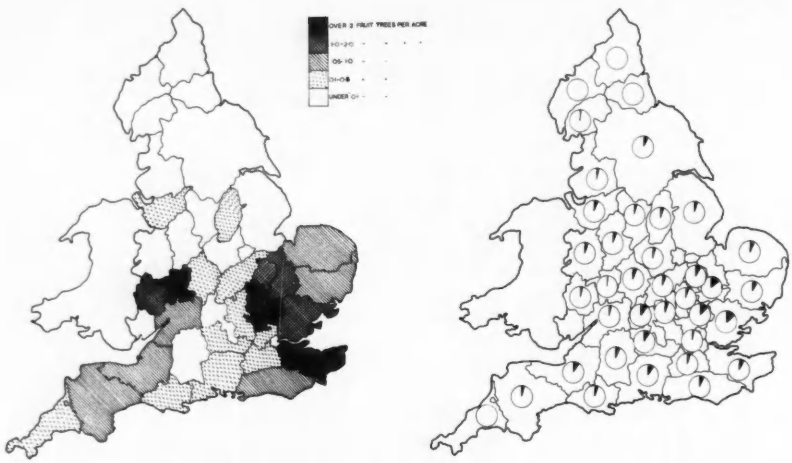


FIG. 3. Breaking down incompatibility with X-rays.

FIG. 4. The stylar sieve for collecting mutations giving self-fertility.

FIG. 5. Having obtained a self-fertile seedling by X-rays (S 3.F), it can be used as male in two types of crosses to produce large numbers of self-fertile progeny from which good-quality seedlings can be selected.



FIGS. 6*a* and *b*. (*a*) Distribution of tree fruits in the counties of England. (*b*) Distribution of plum trees in the relative proportions of self-fertile to self-sterile varieties: black=self-sterile, white=self-fertile. Note the southerly concentration of the self-steriles. (Distributions have been calculated from figures supplied by courtesy of the Ministry of Agriculture.)

Many seedlings have been obtained in apples and pears in a similar way, but they have not flowered yet: there seems to be a reasonable chance that the final result will be similar to that in cherries.

ADVANTAGES OF SELF-FERTILITY

With self-fertile varieties of fruit it will not be necessary to interplant two or more varieties. This will result in considerable economy in cultivation because different varieties often need different treatment; the spraying has to be done at different times, harvesting time may be quite different.

It is very probable that self-fertility would improve the regularity of cropping. For it is known from the work of Bateman, that hive bees, which are now the main pollinators in modern orchards, work over an area which is not much larger than a good-sized fruit tree. The localisation of activity is accentuated when few bees are working such as in the cool conditions often prevailing at blossom-time. This results in self-pollination, giving only a light crop. With self-fertile varieties a heavy crop would result.

Evidence that inadequate cross-pollination is a very real problem comes from plums. The garden plum is a hybrid between a self-fertile species, the myrobalan plum, and a self-sterile species, the wild sloe, and in consequence there are self-fertile and self-sterile varieties in common cultivation. Most of the regular croppers, such as Pershore, Victoria, Denniston's Superb and the damsons, are self-fertile; the more erratic croppers, such as President and Old Greengage, are self-sterile.

At the present time the concentration of orchard fruit growing in the southern counties of England at the expense of the north is very striking (see Fig. 6*a*). One of the causes of this uneven distribution is almost certainly the cooler weather in the north with its effect on pollinating insects and cropping. It is quite likely that when good self-fertile varieties of fruit become available and the necessity for cross-pollination is eliminated it will be possible to grow these varieties successfully farther north.

There is already some support for this view. If we consider the distribution of plums we find that although the self-fertile varieties are grown to a greater extent than the self-sterile types throughout the whole country, the proportion of self-sterile plums is appreciably smaller in the north than in the south (see Fig. 6*b*). The records of planting in the last seven years show that this uneven distribution of self-fertile varieties is being continued and accentuated. In Yorkshire the proportion of self-sterile trees planted recently is only 1 in 20, but in Hertford, Cambridge and Essex a third of the new trees are self-sterile. The emphasis on self-sterile plums in the main fruit-growing areas can be attributed to the better quality of these varieties, but even this advantage is outweighed by climatic limitations in the north.

Cultivated cherries present a less clear picture. Here the self-sterile sweet cherry *Prunus avium* is a different species to the sour cherry *Prunus cerasus*, which is self-fertile. Partly no doubt because of this fact and also because of the much greater demand for sweet cherries, the distribution of the two types is less significant than in plums. Nevertheless the trend is the same, and it is significant that in Scandinavia the only cherry which is grown to any extent is the self-fertile species *Prunus cerasus*.

Other advantages of self-fertility have come to light during the course of the work. Many of the commercially desirable features, which appear to be controlled by recessive genes, may be easier to obtain. For instance, one of the self-fertile cherry seedlings was obtained by self-pollination and is unusually early. This fact may be due to a rare state of homozygosity at one or more loci, seldom encountered by outcrossing but much more likely to be revealed by inbreeding. Artificially induced self-fertility in a normally outcrossing plant can not only facilitate the recovery of useful recessive genes in a homozygous state but, by so doing, can release latent variability within the species and thus increase the range from which to select new varieties.

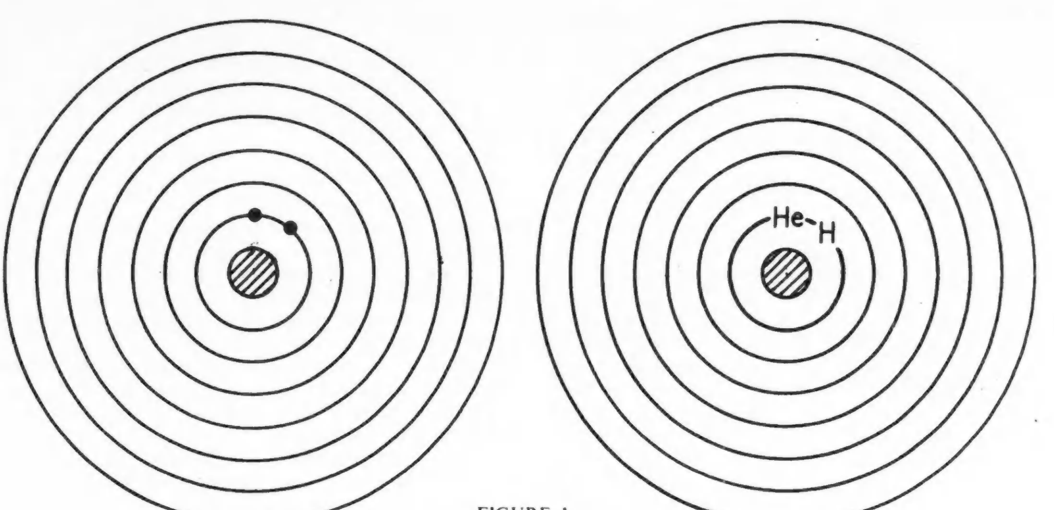


FIGURE 1

A NEW APPROACH TO THE PERIODIC TABLE

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"The periodic system of the elements is the most perfect and the most comprehensive system of classification in the world. It is the most perfect system, because, while based on the internal structure of the atom, it yet extends in such a way as to cover likewise all the outward characteristics. It is the most comprehensive system, because it embraces all the existing building bricks out of which all minerals and rocks, all plants and animals and all celestial bodies, which compose the universe, are made."

Foreshadowed by A. E. Béguyer de Chancourtois in 1862 and J. A. R. Newlands in 1865, the periodic table was fully established by D. I. Mendeleieff in 1869, and it was at once acclaimed to be one of the greatest generalisations in science. Since then the discovery of the application of X-rays to the study of matter in 1912 has endowed the periodic table with a new and much more profound significance. This discovery, as we all know, opened up two hitherto unknown worlds; the world of crystals and the world of atoms. It was the X-ray method as elaborated by Moseley, combined with the quantum theory of radiation that allowed Bohr to establish his theory of atomic structure.

This theory transformed the periodic table, as if by magic, from a mere scheme of classification into a mirror of the electronic structure of the elements. It is not possible to give a short explanation of this conception in a paragraph or so, and here it is enough to say that the quantum theory provides the knowledge that enables us to place the electrons along definite levels or electron orbits which are related to the nucleus of the atom as are the planets to the sun.

Suppose now we take two sheets of paper and on each sheet draw a central blob surrounded by seven concentric circles (Fig. 1). The left-hand drawing we label 'atom' and the right-hand drawing 'periodic table'. We begin by placing a dot representing an electron on the innermost circle of the left drawing and the letter H standing for hydrogen on the innermost circle of the right drawing. An addition of another dot on the left drawing will correspond to an addition of the symbol He (helium) on the right drawing, and so on—the addition of one electron on the map of the atom resulting in the addition of another element in the map of the periodic table, provided that we place the right number of dots and symbols respectively on the successive concentric circles, namely 2, 8, 8, 18, 18, 32 . . . The circles on the left drawing correspond to the electronic shells K L M N O P Q, while the circles on the right drawing correspond to the periods of the periodic table.

This 'game' really means that starting with the lightest of all elements, hydrogen, made of a single proton and a single electron, and adding one proton to the nucleus (neutrons must also be added but they may be neglected here) and one electron to the outer part of the atom, we get the next element—helium. By repeating the process we can theoretically produce all the atomic species composing the periodic table. It also suggests that there exists a parallel between the plan of the electronic structure of the atom and the plan of the periodic table as represented by a series of concentric circles (periods) and radii (groups).

The most familiar form of the periodic table—and the one used by Mendeleieff—is the rectilinear one (Fig. 2),

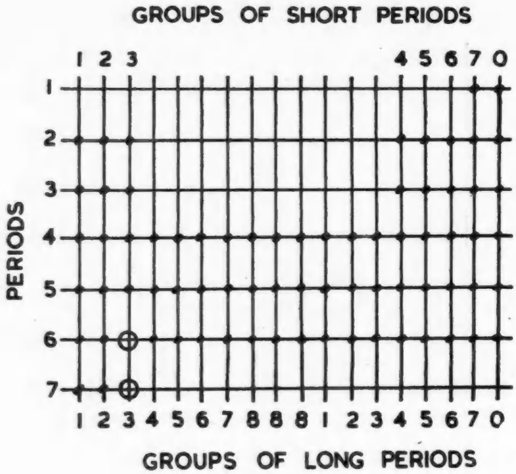


FIGURE 2

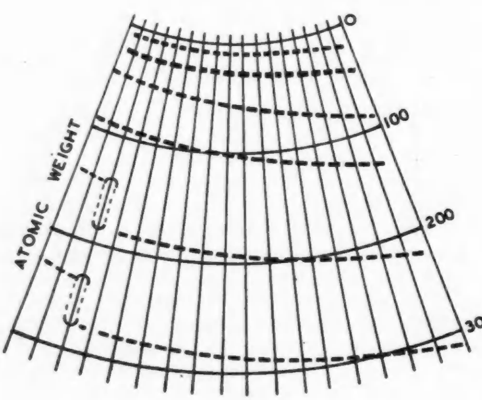


FIGURE 3

but as the purpose of the periodic table is to express the relationship between the elements of the periodic system, one form of the table is not necessarily more valid than another. Thus, by cutting the concentric circles diagram along one of the radii and stretching the cut pattern, one can get the more familiar rectilinear form of the periodic table. Then, if we like, after sloping the period lines we can roll the rectilinear diagram into a cylinder, deform the cylinder into a cone (Fig. 3) and thus join the separate period lines into a continuous helix (Fig. 4), which can be projected on a plane in a form of spiral (Fig. 5). As all these diagrams, after all, represent equivalent projections, so the original concentric diagram which we drew is as good as a spiral.

We can now affirm that the three types of projection—(1) the rectilinear, (2) the helical and (3) the spiral—are the three principal types of the projection of the periodic table. The transformation of our projection into another, which can easily be followed in Fig. 2 to Fig. 5, and can easily be drawn on stiff paper, cut and made into working models, is most instructive to anyone who would like to have a deeper insight into the meaning of the periodic table.

Among these projections the cone-shaped table in the closed or opened form has the advantage of having the atomic weights as an additional dimension. This provides room for the rather awkward groups of 'lanthanides' and 'actinides'. The extension of this principle to the spiral table does not present great advantages and in this projection these two groups are condensed to points.

The spiral periodic table, however, has the advantage of showing a continuous array of elements and a continuous field, and, moreover, the whole network—the spiral lines along which the periods are marked by the convolution and the groups by radii, the whole spider's web network, reminiscent of the terrestrial latitude-longitude network—is a most suitable co-ordinate network for the construction of contour maps. The latitude-longitude terrestrial network, as we all know, allows us to construct all sorts of maps—the usual map showing the surface of the earth, contour maps showing the amount of rainfall, density of population and so on. Using the same principle of cartography, one can also construct contour maps over the periodic spiral to show the distribution of any kind of numerical values associated with the elements.

Suppose, for example, that we are interested in the distribution of the specific gravity among the elements. What we have to do is to place a sheet of tracing paper over the periodic spiral and write over the symbols of the elements figures corresponding to their specific gravities and then, choosing a suitable contour interval, construct a set of contours, each of which corresponds to a fixed value of specific gravity. In this way we shall get a contour map in a form approaching a set of confocal parabolas which will be the map of the 'specific gravity surface' showing the distribution of the specific gravity among the elements. Moreover, the spiral periodic table, like the one in the form of concentric circles, is in fact also the map of the electronic structure of the elements. The ordinal number of each element, called the *atomic number*, is actually the number of electrons contained in a particular atom. The addition of one electron, therefore, corresponds to the move to the next element in the periodic table. The convolution of the spiral, each of which corresponds to a period, may also be considered a symbolic representation of the successive electronic shells of the atom. Suppose we wish to find the electronic structure of titanium, represented on the periodic table by the symbol Ti, we start with the pointer in the centre of the spiral and then move it towards the symbol Ti, crossing the lines of the convolutions, counting two electrons for the first shell, eight for the second, eight for the third and finally four (the number of the group) for the last incomplete shell, and we get 2 . 8 . 8 . 4 as the electronic structure of Titanium.

The actual spiral chosen for our purpose is not the Archimedean spiral shown in Fig. 5, but an oval-shaped spiral in which the geochemically all-important elements, carbon and silicon, are placed in the centre and the short and the long periods are clearly differentiated (Fig. 5). To prevent misunderstanding I would like to point out

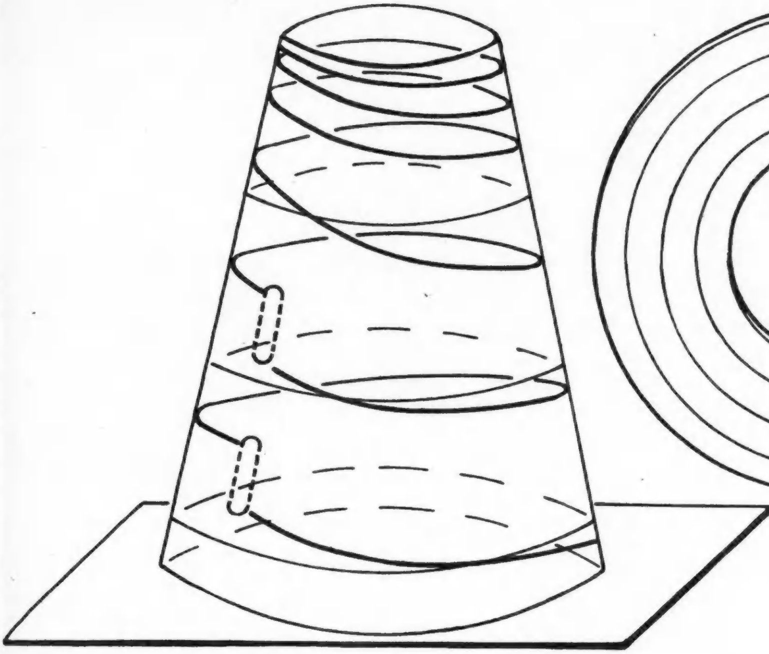


FIGURE 4

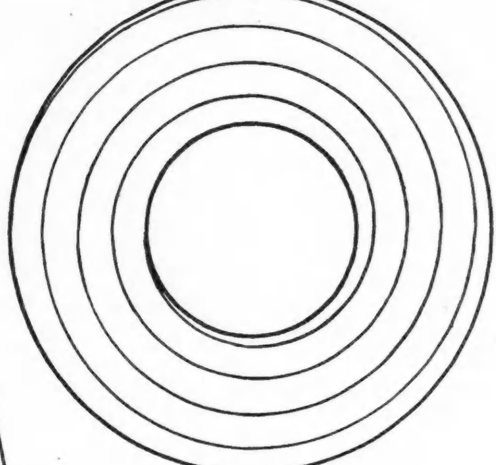


FIGURE 5

that the periodic table in the form of an Archimedean spiral was invented by H. Baumhauer in 1870 and the prototype of the distorted oval spiral—the 'Helix Chemica' —was invented by B. K. Emerson in 1911.

The numerical data which can be used for the contour maps constructed over the periodic spiral can be grouped under three heads: (1) properties of elements, such as specific gravity, ionisation energy, atomic and ionic sizes, melting point, electroconductivity, etc.; (2) properties of compounds, such as hardness, heat of formation, solubility, etc., but only for those groups of compounds which possess a common element or radicle, such as sulphides, sulphates or carbonates, etc.; (3) composition of aggregate bodies, such as organisms, rocks or geospheres.

As an example of mapping, I give a surface showing the average composition (clarkes) of meteorites. The term *clarke* (in honour of F. W. Clarke, the famous geochemist) for 'average composition' was proposed by A. E. Fersman. Thus we can have 'clarkes' and 'clarkes surfaces' of all sorts of bodies, including the cosmos itself. The 'clarkes' map of meteorites (composite average of iron, stone and sulphide meteorites) is based on the data provided by V. M. Goldschmidt and I. and W. Noddack and the contours are marked in logs (base 10) of atomic percentages (Fig. 7). This map, at a glance, shows several interesting features. It shows, for example, that in general the light elements are much more abundant than the heavy elements and that, also in general, the elements of the even groups are more abundant than the elements of the odd groups (counting 8_1 and 8_3 as even and 8_2 as odd). The

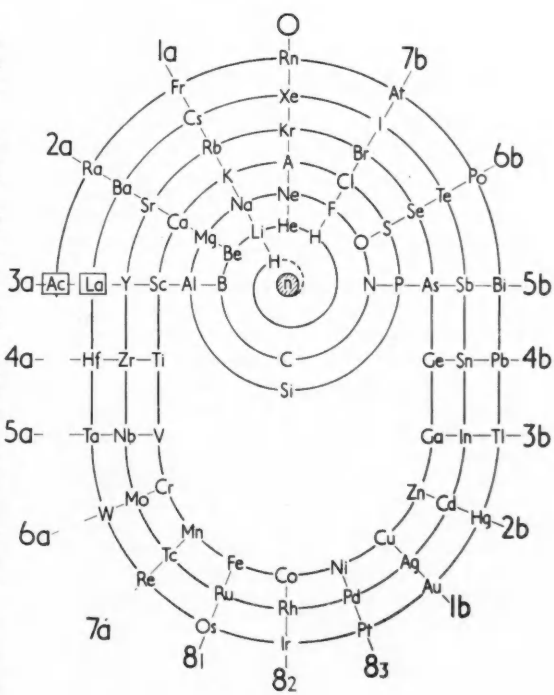


FIGURE 6

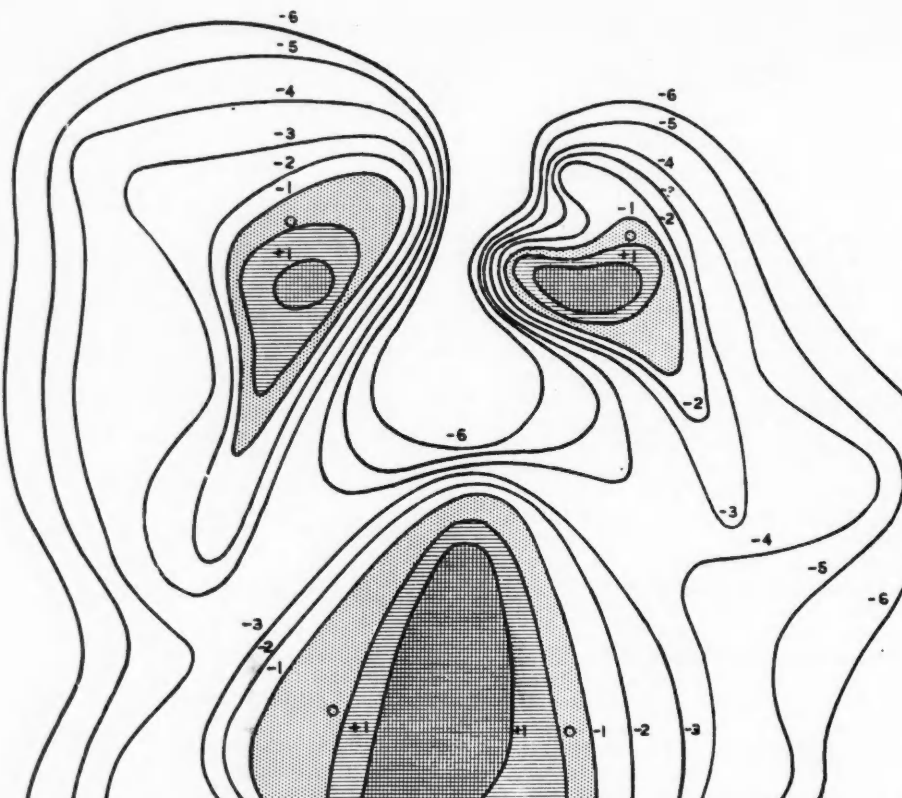


FIGURE 7

map also clearly shows three prominent hillocks corresponding to the three clusters of the four most abundant elements (O 54·10; Si 15·70; Mg 13·50; Fe 9·60; total 92·90) and of the ten subsidiary elements (Al, Ca, Na, K, H, S, P, C, Mn, Ni, total 6·80). These are (1) the oxygen cluster; (2) the magnesium cluster and (3) the silicon-iron cluster. Such a distribution has a profound significance in cosmochemistry and has an intimate connexion with the structure of the elements. The map of the clarkes of meteorites can also be used for comparison with maps of clarkes of other cosmic bodies or parts of such.

We can, for instance, compare the map of clarkes of meteorites with that of the clarkes of the earth's crust, of granite or of any other rock. All this is of great interest in cosmochemistry and geochemistry. Surfaces relating to the properties of elements or compounds can also be used for comparative study and can be of a great help in the study of matter in general and more particularly in geochemistry. Not only as a visual representation of the distribution of properties among the elements or their compounds but also as a visible representation of the functional relation which exists between the properties and the structure of the elements, these maps provide a new method in science, a method which may well have interesting future developments.

(The opening quotation and the diagrams are taken out of *A new periodic table of the elements, based on the structure of the atom*, published by S. I. Tomkeieff, Chapman & Hall, London, 1954, price 10*s*.)

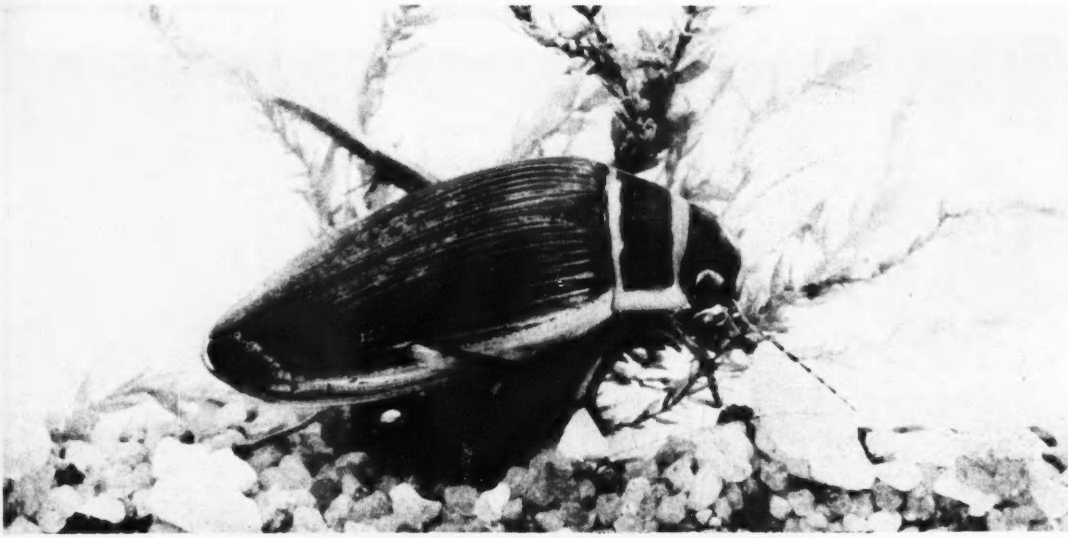


FIG. 1. An adult *Dytiscus* beetle pauses among some water plants before hunting out its next victim. The female of the species may be recognised by its furrowed wing covers.

BEETLE SUBMARINES

ALFRED LEUTSCHER, B.Sc.

Of the three thousand or so beetles which occur in Britain, the majority are terrestrial but two of the largest species are found in water. This is not surprising for ponds characteristically provide an abundance of food, and also a reasonably safe retreat from beetle enemies such as birds. Moreover, the beetle larvae can lurk among the water plants, to pounce out upon any prey which comes within reach.

These two beetles, as well as many other species, spend most of their lives in water.

The first species, the Great Diving Beetle (*Dytiscus marginalis*) is far from being a timid refugee; it is, in fact, the terror of the other animals which live in the same pond or ditch. *Dytiscus*, so named because of its 'fondness of diving', measures a little over one inch in length. Its chestnut-brown body, edged with yellow, is oval and flattened in shape, and the small head is deeply set in the thorax. Its eyes are large; and its antennae long and slender. In its mouth are set a pair of double-toothed mandibles, from which no small animal is safe. Small frogs and fish, newts, tadpoles, other insects—even dragonfly larvae—are set upon voraciously and chewed to pieces.

The adult *Dytiscus* beetle swims gracefully at fair speed. The long hind legs, which are oar-like, propel the body along with each backward thrust, in a sculling action which involves 'feathering' on the return stroke.

What can be said of the adult applies tenfold to the larva, which is not called the 'freshwater tiger' without reason. Its cylindrical body is two inches long, tapers at both ends, and its flat head is set with small eyes and carries two sharp, curved and perforated mandibles. With these the 'tiger' pierces and sucks the bodies of its victims, at the same time securing a firm grip on them with its six long limbs each armed with double claws.

By contrast with this creature, the larger Silver Water Beetle (*Hydrophilus piceus*) seems a harmless giant. It feeds almost entirely on softwater plants, especially algae, of which it bites off pieces and chews them with its mandibles. Its oval and flattened body somewhat resembles that of *Dytiscus*. It is, however, much darker in colour, being almost black in fact. The body length is about $1\frac{1}{2}$ inches. The eyes are smaller and the hind feet less oar-like, having instead sharp projections which enable it to crawl adroitly among the water plants which form its food supply. When it does swim, its progress is slow and awkward, and the legs move in dog-paddle fashion. Its larva, however, rivals *Dytiscus* in its ferocity. Its sooty black body, which is $2\frac{1}{2}$ inches long, is slightly flattened and tapers behind, while the short, broad head possesses small eyes. The larva has a pair of piercing mandibles which it uses to suck the juices out of its prey; water snails are the most common victims, and the easiest to catch.

In their larval stage and as adults, both these beetles need to surface at intervals for air. To do this the larvae rise to the surface by climbing up a water plant; the insect's abdomen is then protruded so that its tip breaks the surface. On the abdomen is a pair of appendages through which air is drawn into the larva's body via the spiracles.

The method in the adult of the two species is strikingly different. *Dytiscus* floats upwards from the pond's depth, with its tail uppermost, until the tip of the abdomen just breaks the water. The hard wing covers are raised slightly, and air passes underneath them. As the beetle dives beneath the surface, air is held by the hard, chitinous hairs

FIG. 2.
THE LIFE HISTORY OF THE GREAT DIVING BEETLE (DYTISCUS)

which cover the animal's skin, and can usually be seen protruding beyond the wing cases as a shiny bubble. Sometimes too much air is carried by the beetle, which then has some difficulty in submerging. It may even release some of the air, which breaks away as a tiny bubble. This reservoir of air under the wing cases is tapped by the two largest spiracles, which are placed towards the hind end of the body where the bubble is held.

Hydrophilus, on the other hand, rises at its leisure, usually crawling up the plants. When just below the surface, it tilts its body to one side in the nearly horizontal position. One of its long antennae is then raised clear of the surface. As the antenna lifts it draws out an air film from the reservoir, and this merges with the outside atmosphere at the moment the insect breaks the surface. A temporary air passage is formed between the antenna and the thorax. Air is drawn in by a gentle pumping action of the wing covers and abdomen, and it collects in two masses—one under the wing covers and the other under the abdomen—which are held by the hairs on the insect's body. Light reflecting from the lower air film gives a silvery appearance to the beetle's abdomen; the effect of the silvery air film is suggestive of newly applied solder.

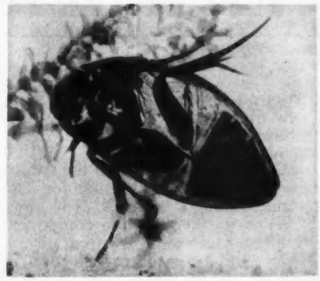
The air film which is trapped among the hairs may be likened to the tiny bubbles which can be seen on the back of a human hand when it is gently lowered into water. The main spiracles which open near the front end of the beetle tap this air supply as required.

The two beetles also differ in their method of egg-laying. A female *Dytiscus* attaches itself to the stem of a water plant, such as a reed or water-lily, and by means of her ovipositor, which is armed with two sharp plates, she makes a cut in the stem. Within each separate cut a single egg is laid.

Egg-laying in *Hydrophilus* is a more elaborate affair. At the surface of the water the female beetle constructs a cocoon which is shaped like a flattened sphere, whitish in colour and about an inch long. By five or six hours' work, mostly done in an upside-down position, she seals off this curious object after she has laid about a hundred eggs, which are attached inside it to the roof surface. One end of the cocoon is drawn out in a vertical mast-like projection. This 'mast' serves no useful purpose; it is not a float; for the cocoon is normally anchored to some floating object, and it cannot be used as a ventilator since its passage is blocked.

The larvae which hatch out grow up, and after completing a succession of moults are fully developed in about four weeks. What follows seems rather unusual in beetles which are otherwise so aquatic in habits and design. The grown larva in both species leaves its pond and journeys across the damp ground, travelling as much as ten or more feet away from the water's edge. Reaching some obstacle such as the base of a pond's bank, it commences to burrow. The larva usually succeeds in disappearing from sight within six to eight hours. .The spherical cell it has bitten away is then sealed off, and with its final moult the insect pupates inside the cell.

Little was known about this stage in the life of these beetles until 1934, when a full account was published by the late Hugh Main, who was a keen observer and an entomologist with infinite patience. He kept the larvae of both



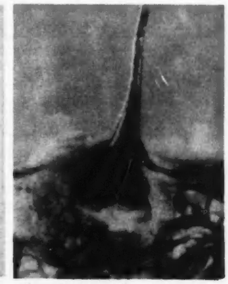


FIG. 3 (*left*). Female of Silver Water Beetle (*Hydrophilus piceus*).
FIG. 4. Egg raft of *Hydrophilus piceus*, showing the 'mast'; just below this is the hole made by emerging larvae.

beetles in aquaria containing only a shallow layer of water and in these he constructed banks of earth into which the pupating larvae could burrow. He was able to observe the larva's movements and labour through the glass sides of the tanks.

In its earthbound cell the pupa rests for about three weeks. The final metamorphosis and emergence of the adult was watched and recorded as long ago as 1809. The eyes, legs and body of the pupa become visible as they darken, while the wings and body remain white. The outer skin then splits down the back, and with much wriggling and twisting the perfect insect emerges. By turning on its back and kicking with the legs it is able to discard the skin, and then proceeds to crawl out through an opening which it bores through the roof of the cell. At first the pale wings are held out stiffly until they darken and finally become firm; eventually they are folded and tucked away under the wing cases, and the beetle turns on to its feet.

A study of the mechanism of these miniature submarines might well provide inspiration for new discoveries in our own mechanical world. The mechanism of air intake, the floating cocoon, the male's suckers and the oar-like leg action, are all worth study by naval architects, who might well learn as much from water beetles as the aircraft designer has learnt from birds.

On the less practical side there are many unsolved problems to excite the naturalist. Adult beetles will appear in a ditch, a pond or even a water-filled bomb-crater, stay there for months, even years, and then disappear as suddenly and mysteriously as they came. Why should this be? Abundance or shortage of food may be a factor controlling their migration. The state of the water seems to make little difference, for these beetles occur in the cleanest ponds as well as the filthiest. How do they find new homes? *Dytiscus* gives off an unpleasant odour which may attract others of its kind. Perhaps the *glint* of water draws them home, for these water beetles often blunder into the glass of windows and of greenhouses. A friend of mine once kept a *Dytiscus* in an aquarium, but omitted to put a cover on it. One morning the beetle had gone. Two days later he found it among some fish in another aquarium, where it had dined royally. To reach this new home it had to negotiate a staircase and a winding passage. The next day it had returned to its original home!

(*Fig. 2 is reproduced by courtesy of the B.B.C. Publications Department. Photographs by Lionel E. Day, F.R.P.S.*)

FAR AND NEAR

Night Sky in September

The Moon.—Full moon occurs on Sept. 12d 20h 19m, U.T., and new moon on Sept. 27d 00h 50m. The following conjunctions with the moon take place:

1d 15h	Venus in conjunction with the moon		Venus	3° N.
2d 14h	Saturn	„	Saturn	7° N.
7d 10h	Mars	„	Mars	3° S.
21d 16h	Jupiter	„	Jupiter	1° N.
29d 08h	Mercury	„	Mercury	3° N.
30d 02h	Saturn	„	Saturn	7° N.
30d 22h	Venus	„	Venus	1° S.

In addition to these conjunctions with the moon, Jupiter is in conjunction with Pollux on Sept. 12d 14h, Jupiter 6° 7′ S., Venus is in conjunction with Saturn on Sept. 16d 03h, Venus 6° 1′ S., Mercury is in conjunction with Spica on Sept. 23d 17h, Mercury 0° 6′ N., and also with Neptune on Sept. 26d 05h, being 3° 7′ S. of Neptune.

The Planets.—Mercury sets too soon after the sun for favourable observation. Venus, an evening star, sets at 19h 50m, 19h 10m and 18h 25m at the beginning, middle and end of the month respectively. The visible portion of the illuminated disk rapidly decreases from 0·513 to 0·341 during September, though the stellar magnitude increases from −4·0 to −4·2 owing to the decrease in the planet's distance from the earth from 67 to 46 millions of miles. The close approach of Venus to the moon on Sept. 1 and 30 will be a pretty sight in the western sky if the weather permits. Mars sets at 22h 50m, 22h 30m and 22h 15m on Sept. 1, 15 and 30 respectively, but owing to the planet's rather large southern declination—about 26°—it will not be very favourably placed for observation in the British Isles. Jupiter rises at 0h 50m, 0h 10m and 23h 25m at the beginning, middle and end of the month respectively, and is visible in the early morning hours in the constellation Gemini in which it has an easterly movement. Saturn sets at 20h 40m, 19h 45m and 18h 50m on Sept. 1, 15 and 30 respectively—in the latter case just over an hour after sunset. During the month it moves from Virgo to Libra and is a little brighter than a first magnitude star; it is not close to any bright star during September but is easily identified. Its fairly close approach to the moon on Sept. 2 and 30 has been noticed under conjunctions. Autumnal equinox is on Sept. 23d 14h.

The star Capella, the brightest star in the constellation Auriga, can be seen late at night towards the NE. and is easily identified by drawing a line through δ and α Ursae Majoris, that is, through the fourth and first stars in the Plough, and prolonging it a little more than four times the distance between these stars. It is a very close double star and the masses of each component are about 3·9 and 3·2 that of the sun, their distance apart being only 80 million miles. As the system is about 45 light-years distant (a light year is 6 million million miles) it is not surprising that the knowledge about the two components was not obtained visually but by means of the spectroscope which has been responsible for detecting many very close binaries. The apparent distance apart of the two components is comparable with the apparent distance of two points a foot apart seen 700 miles away. Another interesting fact is that about 12 minutes of arc—less than one-half of the moon's apparent diameter—from the bright pair there is another companion which is also a double, but both are rather faint. Hence Capella is a quadruple system.

Endeavour Prize Essay Winners, 1954

The first 'Endeavour' Essay prize of fifty guineas has been awarded to DOUGLAS W. ALLAN, aged twenty-three, of Ontario, Canada, for an essay on Heat of the Earth; he is a graduate of the University of Toronto.

The second prize of twenty-five guineas has gone to P. B. TOMLINSON, aged twenty-two, of Leeds, for an essay on The Span of Life. A graduate of Leeds University, he was awarded an Agricultural Research Council Research Studentship in 1953, and is engaged in post-graduate research in Plant Anatomy.

The winner of the third prize of fifteen guineas is C. D. LUSTIG, aged twenty-one, of London, for an essay on Colour Photography. He is at present studying at Christ Church College, Oxford.

Special junior prizes of five guineas were awarded to:

1. S. M. F. SHEPPARD, aged sixteen, a student at St. Paul's School, West Kensington, London, for an essay on the Upper Atmosphere.
2. R. D. WILLIAMS, aged seventeen, a student at Birkenhead School, for an essay on Colour Photography.

The Shortage of Science Masters and British Technology

Two documents relevant to the above subject have just been published. The first is the F.B.I. report on "The shortage of Science Teachers". Almost all the recommendations which it makes, and which would undoubtedly help to relieve the shortage if they were implemented, have already been published in DISCOVERY—most of them were, in fact, first advocated in our columns. The one new feature in this report is the suggestion that four grades of science masters should be introduced; the salaries proposed for these four grades are as follows:

Grade I: Starting salary £580 for pass and 3rd class honours degree; £620 for 1st and 2nd class honours degree at age 24—advancing by £20 increments to £900.

Grade II: A £50 increment on promotion and an annual advance of £25 to a maximum of £1000.

Grade III: An increment of £60 on promotion and annual increases of £30 to a maximum of £1300.

Grade IV: An increment of £80 on promotion and annual increases of £40 to a maximum of £1500.

The report adds the following comment: "We consider that £900 might represent the maximum salary for, say 50% of the graduates, £1100 for, say 30%, £1300 for, say 15% and £1500 for, say 5%. Bearing in mind that we are recommending the abandonment of special allowances, Grade 1 may not represent any substantial increase in income for 50% of the graduate teachers, but the new salary structure does provide opportunities for promotion. Selection for promotion to the higher grades should be made by reason of merit rather than by age seniority, promotion generally being accompanied by an increase in responsibility." This F.B.I. report emanates from a special committee set up by the Federation of British Industries; the names of its members were printed in DISCOVERY in May 1954 (p. 212).

* * *

The second document is the Memorandum on Higher Technological Education. This was drawn up by a special sub-committee of the Parliamentary and Scientific Committee, which is an unofficial group of members of both Houses of Parliament and representatives of certain scientific, engineering and technical institutions. The members of the sub-committee were as follows: Lord Glyn (*chairman*), Viscount Falmouth, Austen Albu, A. G. Bottomley, A. J. Champion, Sir Hugh Linstead, I. J. Pitman, W. Robson-Brown, Sir Wavell Wakefield, W. T. Wells, I. Winterbottom and Lt.-Cdr. Christopher Powell (*secretary, Parliamentary and Scientific Committee*).

This memorandum recommends that a few colleges of technology should be selected and granted a Royal Charter. These Royal Colleges of Technology should be provided with strong governing bodies having adequate representation of industrial, commercial and university interests in the region as well as of the Local Education Authorities, the Ministry of Education and the professional institutions. Here one cannot escape the feeling that there is a large measure of wish-fulfilment in this suggestion, since the various interests mentioned in the last sentence show no sign of being capable of agreeing about the fundamental features of higher technological education; indeed it is no exaggeration to say that they do not seem to be able to agree upon their definition of 'higher technological education' (some apply the term to *undergraduate* students, others restrict it to *post-graduates*), and there is certainly great confusion as to the differences between 'technicians' and 'technologists'. The sub-committee advocates that the appropriate award of its hypothetical Royal Colleges of Technology should be a Bachelor of Technology. The report adds, however,

that "no doubt other types of Award will be developed by the Colleges themselves for technologies which do not come up to the scientific and professional standard here envisaged". This ambiguous remark is, however, qualified by this sentence: "*It is important, whatever first Award is given, that it should be of such a standard as to qualify its holder for post-graduate work in a Royal Chartered College or University.*"

The clearest section of this memorandum is that dealing with the shortage of science masters. It states, among other things, that of the 8000 State scholars in Britain only about 600 are specialising in science. It considers that many students who have studied no science at school "can very usefully go on to study Science or Engineering at the University". The report mentions, with obvious regret, the existence of many new secondary schools in which accommodation for practical work is almost non-existent, so that science, if it is taught, is taught largely from textbooks and blackboards, with unfavourable reactions on the teachers' success.

The sub-committee also recommends that some body—possibly organised jointly by the Federation of British Industries, the National Union of Manufacturers and the Associated British Chambers of Commerce, in consultation with the professional institutions—should assume the primary duty of publicising at schools what careers are available in industry on the technological side. The report cites the case of one school where only one-tenth of the notices on the careers notice-board mentioned industrial jobs. For this unfortunate state of affair the sub-committee sees no short-term remedy; "it will need intensive and long-term efforts by industry and the professional institutions". One is reminded here of the interesting careers booklets produced by two of these institutions, namely the Institution of Chemical Engineers and the Institute of Physics.

• • •

In the first editorial in the last issue we referred to Prof. Sir Francis Simon's article in the annual review of British industry published by *The Financial Times*. By misadventure an error crept into our passage referring to the cost of a British M.I.T. Sir Francis Simon's original sentence dealing with this matter read as follows: "The cost of setting up a modern Institute of Technology of university standard would not be more than £10 million." The figure of £10 million represented the *capital* cost, not a running cost as our editorial implied.

A Solar Battery

The Bell Telephone Laboratories have announced the invention of an electric battery which uses sunlight as its fuel, and which develops enough power to run toys or transmit voices for short distances over wires. An efficiency of 6% is claimed for the battery in converting sunlight directly into electricity, which compares favourably with the efficiency of steam and petrol engines in contrast with other photoelectric devices, which have a rating of no more than 1%.

The experimental solar battery uses strips of wafer-thin silicon about the size of an ordinary safety razor blade. These strips are highly sensitive to light, and can be linked together electrically and deliver power from the sun at the rate of 50 watts per square yard of surface.

The solar battery, along with other silicon devices demonstrated at the laboratories, would seem to be an offshoot of a broad study of silicon and its possible application in modern electronics. An important feature of these silicon devices is that they can operate at much higher temperatures than other crystal rectifiers now in use.

Plants that Concentrate Aluminium

Certain plants have the habit of concentrating odd elements: there are for instance several plants which accumulate selenium (and which can therefore render pasturage and hay poisonous to cattle), and most people are aware of the fact that seaweeds concentrate the element iodine. In view of the flocculating effect which the trivalent aluminium ion has on colloidal substances, it is not surprising to find that this metal is concentrated by plants. A very interesting paper on this subject, entitled "Aluminium accumulation in the Australian-New Guinea Flora" by L. J. Webb of the C.S.I.R.O. Division of Plant Industry in Brisbane, is published in the *Australian Journal of Botany* (Vol. 2, No. 2, June 1954).

Eighty aluminium-accumulating species have been detected among 1324 species tested from the Australian-New Guinea flora. Accumulation was most strongly developed in certain dicotyledons (69 species) and ferns (11 species).

A high aluminium content of the organs of accumulating plants appears to be associated with normal metabolism. Recorded accumulators are mainly restricted to what are usually regarded as the more primitive groups in dicotyledons and ferns, suggesting that accumulation is a physiological relic in these groups.

Obligate accumulators are confined to leached acid soils from a variety of parent materials, in comparatively high-rainfall areas. The re-deposition of aluminium in vegetable debris beneath Australian rainforest communities dominated by accumulators (e.g. *Ceratopetalum apetalum*) may be an important ecological and pedogenic factor.

There is evidence that accumulation is an adjunct of specialisation (i.e. relatively narrow physiological tolerances), chiefly among tree species able to exploit impoverished soils in relatively primitive, generally tropical, mesic habitats. Accumulation seems a useful special character to supplement other data in the clarification of some taxonomic problems.

Catalogue of Unesco Publications

A 92-page catalogue of Unesco publications has been produced, and this can be obtained on application to H.M. Stationery Office, P.O. Box 569, London, S.E.1 or its provincial offices.

The World's Helicopters

There is considerable topical interest in the 1*s*. 6*d*. booklet issued by Iliffe's which is entitled *Helicopters of the World*. This sixteen-page review contains descriptions, photographs and three-view general-arrangement drawings of the world's helicopters. It is clear that, although some of the most outstanding designs are American, Britain's progress in this realm has been by no means negligible, and that leading British makers are pursuing their individual researches along clearly promising lines. Some French machines of real merit also have their place, and two types of Russian helicopters are illustrated from actual photographs.

A companion booklet is *Military Aircraft of the World* by H. F. King. This contains fifty pages and costs half a crown. Many of its very numerous illustrations appear for the first time, and a special feature is a spread of drawings depicting, to a uniform scale, the world's jet bombers. Here is seen the remarkable diversity of modern design—the crescent-wing Victor, the delta-wing Vulcan and the Boeing B-52 (the world's largest bomber), with its eight turbo-jets slung beneath its vast back-swept wing. Russian aircraft are conspicuous by their almost complete absence from this review; such data as are given merely serve to whet one's appetite for further information.

Heavy Water and Atomic Power Project in N.Z.

In view of prospects of utilising heavy water in certain types of nuclear power reactors, the British and New Zealand Governments have agreed to proceed with a project for producing heavy water and power from geo-thermal steam in the Wairakei District of North Island. Last year Britain decided on economic grounds *not* to go ahead with the project then under consideration, but the liaison in this field has been maintained. The plans at present under examination provide for a useful contribution to North Island's electricity supply and for subsequent extension of the plant should this prove desirable.

Australia's New Uranium Plant

Australia's biggest uranium plant will be officially opened by the Prime Minister, Mr. Menzies, at the Rum Jungle uranium field in the Northern Territory on September 17, when large-scale production of uranium oxide will begin for sale to Britain and the U.S.A. for defence purposes. The plant will be the first full-scale one producing uranium ore in Australia. Output will be about twice as much as originally planned. A large quantity of ore is now stockpiled ready for treatment and prospecting for other ore bodies is continuing.

Research Stations on Drifting Ice-floes

According to *Soviet News* (published by the Soviet Embassy in London), the Central Administration of the Northern Sea Route, jointly with the U.S.S.R. Academy of Sciences, has established two scientific stations on drifting ice-floes in the Central Arctic in order to carry out further research in the Arctic Ocean.

The scientific work at both stations is being carried out in line with a programme embracing all fields of knowledge of the Arctic. Laboratories have been set up at the stations. Soundings, observations of the atmosphere and of the geology of the ocean bed, and various other oceanographic observations are taken regularly. The members of the stations are housed in mobile sectional huts and heated tents and have the necessary supplies of food. The living accommodation is heated by coal and gas. Autogyros, tractors and motor vehicles are used in keeping the stations supplied.

One of the scientific stations, whose personnel landed on the ice at latitude 86° 00′ N. and longitude 175° 45′ W., is headed by A. F. Treshnikov, candidate of Geographical Sciences. The station is drifting in a north-easterly direction and on July 15 had reached latitude 88° 02′ N. and longitude 151° 40′ W. The other scientific station is headed by E. I. Tolstikov, candidate of Geographical Sciences. The personnel of this station landed on the ice at latitude 75° 48′ N. and longitude 175° 25′ W., and the station is now drifting in a north-westerly direction. The position of the station on July 15 was latitude 77° 22′ N. and longitude 174° 20′ E.

A high-altitude air expedition landed the parties on the drifting ice. This expedition at the same time carried out scientific research in the central part of the Arctic Ocean. A detailed study was made of the area in the neighbourhood of the Pole, in the belt of the submerged Lomonosov range and the area of the continental slope in the northern part of the Chukotsk Sea.

Regular radio and air communication is maintained with the drifting scientific stations. Letters, parcels and newspapers, and fresh vegetables and fruit are delivered from the mainland to the stations.

New Leaflets on Vacuum Equipment

W. Edwards & Co. (London) Ltd., the firm that specialises in high-vacuum equipment, has just published several new technical leaflets, which readers can obtain if they write to this firm—the address is Manor Royal, Crawley, Sussex—and mention DISCOVERY. The numbers of these new leaflets, together with some indication of the specific apparatus they describe, are given below:

B.118/1: this is devoted to Edwards's complete range of oil and mercury diffusion pumps, from the small one- and two-inch laboratory models, to the large 24-inch pump for special industrial applications; full details are provided, with speed curves and a specification table.

E.141/3: this new micro-moisture determination apparatus was designed for use during our extensive research into freeze-drying. It became necessary to know the exact moisture content of an ampoule dried substance, and as this amount was sometimes as small as 10^{-6} grammes this apparatus was necessary in order to measure such micro amounts accurately. This instrument should prove extremely useful not only to workers interested in freeze-drying but also to other fields such as chemical and pharmaceutical product manufacturers.

D.141/1: more and more components have to be exhaustively tested for leaks before their use in a vacuum system, and this leaflet describes the new palladium barrier leak-detection gauge. Vacuum plant employing this technique is suitable for many industrial uses, and two such units are depicted in the leaflet.

E. 149/2: the technique of moulding thermo-plastic sheet with the aid of vacuum is now being employed by the plastics industry and is being used on a large scale in America. Edwards have designed a single and inexpensive machine for this purpose and which is within the price range of both large and small plastic users. The 'Speedivac' 1S450 pump unit is fitted, displacing 15 cubic feet of air per minute, thus enabling very rapid forming cycles to be performed. (Ex-works price, £350.)

E.148/1: during the initial experimental work and later for the actual production of Edwards's 'Circseal' range of ground glass cone joints, the firm developed several useful glass working machines. One of these, a small lathe, obviously had a number of uses for both industrial glass shops and research centres making their own glassware. This unit (G.3) is described in this leaflet; its ex-works price is £250.

Application of Scientific Research to Industry

Three bodies, the Royal Society of Arts, the British Association for the Advancement of Science and the Nuffield Foundation have established a joint *Science and Industry Committee* to investigate the possibility of speeding up the application to industry of the results of scientific research. From the 'Conditional Aid' funds the Board of Trade has made a grant to this committee to help it to begin research into the whole problem.

For some years there has been a feeling that while British fundamental research equals and frequently surpasses in excellence and achievement similar research in other countries, the translation of the results of research into industrial action has often been too slow. The British Association for the Advancement of Science set up a committee to discover the factors which caused this slowness. After preliminary investigations, this committee was convinced that the work was urgent and so important that the Association should seek the co-operation of other bodies in sponsoring a study of the many problems involved.

The new joint committee is well aware of the fact that much work is going on at the universities and in industry, all of which may serve to reduce the gap between research achievement and industrial application, but the committee's terms of reference, which have been accepted by the Board of Trade, are comprehensive. They include the making of a systematic and scientific appraisal of the whole problem, surveying the research already under way elsewhere in order to see what further study is needed; the identification of those factors which determine, in different industries and in different types of firms, the speed of application of new scientific and technical knowledge; the examination of their relative importance, their interrelation and their correlation with the characteristics of the firm or industry; the collection of evidence of the effectiveness of measures already taken to speed up the application of science in industry, or to remove hindrances to such application; and the examination of the possible results of other proposed measures.

The chairman of the committee is Professor C. F. Carter, and some work is already in progress and centred on two research units; one at the University College of North Staffordshire directed by Professor E. R. Williams, and one at the Queen's University of Belfast, directed by Professor C. F. Carter.

The members of the joint committee are:

Appointed by the Council of the Royal Society of Arts:

Sir Ernest Goodale, Mr. A. C. Hartley, Dame Caroline Haslett, Sir John Simonsen. The secretary of the Royal Society of Arts attends *ex officio*.

Appointed by the British Association for the Advancement of Science:

Dr. T. E. Allibone, Mr. M. G. Bennett (treasurer), Professor A. J. Brown, Professor C. F. Carter (chairman), Mr. A. C. Hartley (also appointed by R.S.A.), Professor K. S. Isles, Professor H. D. Kay, Professor J. A. L. Matheson, Dr. R. E. Slade, Professor M. Stacey, Professor B. R. Williams (secretary), Dr. T. Wilson. The secretary and assistant secretary of the British Association attend *ex officio*.

Appointed by the Trustees of the Nuffield Foundation:

Professor A. K. Cairncross, Dr. Barnes Wallis, Mr. A. H. Wilson. The director and assistant secretary of the Nuffield Foundation attend *ex officio*.

New Films of Scientific Interest

The latest list of additions to the I.C.I. Film Library (Imperial Chemical House, Millbank, S.W.1) includes the following titles:

The Glassblower; Making Tyres; Some Uses of Alkathene; Sulphamethazine for Poultry; Making Lead Shot; Locusts at Hawthorndale, the laboratory maintained by I.C.I.'s Central Agricultural Control where every year thousands of locusts are reared so that the efficacy of new insecticides against these pests can be tested.

Two new films have been made in collaboration with the Turkish Ministry of

Agriculture. The first—*Health means Wealth*—deals with the effect of worm infestation and the use of phenothiazine. The second, entitled *Springtime Enemy*, is about tick fever (piraplasmosis) and its treatment with a specific drug. A third agricultural film, *Bahtim Story*, describes the activities of the veterinary research centre near Cairo where Egyptian livestock diseases are studied.

Synthetic Mica goes into Large-scale Production

Synthetic mica is going into production for the first time in the U.S.A. The manufacturer will be the Mycalex Corporation of America, which has been co-operating for several years with Federal Government agencies on a pilot operation. By the end of this year the company believes it will be able to turn out high-grade mica.

It is anticipated that synthetic mica will cost more at first than natural mica, but with the increase in production volume prices will come down to a range comparable with natural mica. So far, synthetic mica has been made mostly in small crystals, but the company believes that in a few years they will solve the problems of making larger crystals. Up to date some 200,000 lb. of synthetic mica has been produced in the pilot plant.

THE BOOKSHELF

Economic Botany

A Text-book of Useful Plants and Plant Products by Albert F. Hill (*New York and London, McGraw-Hill, 1952, 560 pp., 56s.*)

Good books on economic botany have become a rarity in this century, though good monographs dealing with individual crop plants (e.g. S. C. Harland's *The Genetics of Cotton*) have continued to be published, and there is no lack of monographs written from the chemical point of view—examples are Hilditch's *The Chemical Constitution of Natural Fats* and J. Grant's *Wood Pulp and Allied Products*.

This volume is written by an economic botanist of Harvard University, and published in McGraw-Hill's botanical series edited by E. W. Sinnott. It originally appeared in 1937.

Designed to meet the requirements of Harvard students taking a one-semester course in the subject, its scope is limited and the author goes so far as to say that "only the surface of economic botany can be scratched". There is naturally an American bias about his choice of crop plants, but this does not substantially reduce the value of the volume since the U.S.A. exploits an exceptionally large range of economic plants.

The author has purposely avoided going into details of morphology and into the agricultural and commercial aspects of the plants which he discusses. This limitation is in fact an advantage in an elementary work of this kind, and anyone who wants supplementary information can trace it through the 89 important reference books published since 1936 which are listed. (This valuable list contains both general and specialised references, the latter falling into four categories—viz. industrial plants, and plants yielding drugs, food and food adjuncts (e.g. spices, coffee). This useful bibliography is followed by a list of films and film strips relevant to the subject, though not all of these are likely to be available in Britain. Other textbook writers might follow Hill's lead and give details of available teaching films, etc.

Australian Seashores

By William J. Dakin (*London, Angus and Robertson, 1953, 373 pp., 99 plates, 23 line drawings, 45s.*)

This book represents an immense amount of hard work. An author setting out to write about English seashores has a great and rapidly growing literature at his disposal; his species are all identified and well known, and his task is mainly one of selection and presentation. Compared with that, the task that faced the late Prof. W. J. Dakin and his able co-authors Miss Isobel Bennett and Miss Elizabeth Pope was infinitely harder in that they had virtually new ground to break: as a preliminary, much patient and original research was needed. Indeed this book, although written in an easy flowing style that any intelligent layman can understand, is undeniably a serious and valuable contribution to biological literature and it will for long be used as a handbook by all who collect on the non-tropical shores of Australia, especially those of the south-eastern corner. Marine biologists in other countries who may never visit this southern continent will find here a wealth of accurate information about the rich plant and animal life of its warm temperate inter-tidal rocks and sands and find it sufficiently detailed to be invaluable for comparison with their own and perhaps colder and less diversely populated shores.

The book is divided into two parts. The first deals with some general aspects of inter-tidal biology, the second with the plants and animals arranged and discussed in order of classification. This second section is the longer and more valuable: it is distinguished by a very large number of photographs, a few of them in colour. These illustrations are of the highest quality and are often of animals *in situ* on the shore or alive in aquarium tanks. We can well believe that this large collection of pictures took many years to acquire; they are deserving of much praise and will be greatly appreciated by all who have to identify animals from Australian seashores.

D. P. WILSON

Almroth Wright

By Leonard Colebrook, F.R.S. (*London, Heinemann Medical Books, 1954, 286 pp., 21s.*)

This biography is inspired by the mutual respect and friendship between two men which began when as "a raw student in his (Almroth Wright's) pathology class" at St. Mary's Hospital, Paddington, the author first saw the master at work. Sir Almroth Wright (1861–1947) belongs to that great company of pioneers which, as Colebrook points out, includes Claude Bernard, Pasteur, Koch, Metchnikoff and Ehrlich. Every Serviceman whose arm has received an injection of TAB vaccine has cause to be indebted to him, for in the First World War he brought this anti-typhoid vaccine into production; even the acute discomfort which this particular injection can give rise to is a negligible thing compared with the protection which it confers. Wright was the son of an Irish clergyman and his Swedish wife, and his Irish 'love of a fight' was as important as his skill in bacteriological matters when it came to getting the anti-typhoid vaccine accepted. The Medical Corps of the British Army was slow to adopt it, and in the South African War only 14,628 men were immunised (inoculation was then purely voluntary) out of the 328,244 men who embarked during those three years. In view of the fact that the treatment was voluntary and that it "did often make men feel as if they had been kicked by a horse and sometimes put them off duty for a day or two with fever", it is really surprising that so many were immunised. Active opposition to the treatment went to extraordinary lengths: for instance, some batches of vaccine were thrown overboard from troopships in Southampton Water, to be returned to Wright by the coastguards who picked them up!

Following up the medical history of the men who had been inoculated proved difficult; the medical records were unreliable in many ways and for a variety of reasons—there was, for instance, the Medical Corps sergeant who when asked why he marked all typhoid cases as having been inoculated replied, "I always score them up as inoculated, for it stands to reason that if they get typhoid fever they *must* have been inoculated!" The Army did in fact suffer many losses through typhoid: out of 58,000 cases, there were 9000 deaths. After the war Wright urged that inoculation should be continued, and that continuous research should be organised with a view to improving the technique. Wright found further obstacles blocking progress here, including Prof. Karl Pearson, the statistician, who maintained that the existing figures did not justify the claims that were made for anti-typhoid inoculation. Pearson's thesis provoked a heated controversy in the *British Medical Journal*; from this we see that Wright was "prepared to act on probability (as we so often have to do in human doctoring), rather than on mathematically established certainty. He, unlike Pearson, had too often seen men dying miserably from typhoid fever.... [Pearson] was not unduly worried by the

SIR ALMROTH WRIGHT

A drawing by Francis Dodd, R.A.

prospect that men might go on dying of typhoid fever while scientific proof was being obtained by such an ideal (and perhaps impracticable?) trial." Colebrook is critical of Pearson's attitude: he "underestimated the very real difficulties in obtaining reliable data in connexion with human disease; and perhaps also overestimated the reliability of his technique as a practical guide". Colebrook's concluding comment on this matter is that "if Pearson had had his way . . . the immense benefits (of anti-typhoid inoculation in the Army) would have been postponed for many years and would probably not have been available for the 1914–18 war". Fortunately for the troops the War Office's expert committee decided to appoint to every unit of cavalry, infantry and every brigade of artillery going overseas an officer trained for the work by Colonel Leishman to keep careful records of all inoculations and all typhoid 'casualties'. By 1909 it was established from these records that the death rate from typhoid fever was only 0·38% per thousand *inoculated* men, as against 3·93% for *uninoculated* men. One of Almroth Wright's most important supporters was Lord Haldane, brother of Prof. J. S. Haldane and uncle of J. B. S. Haldane. Lord Haldane was the Minister for War and decided that to put over the inoculation policy it was necessary to 'build up' Wright as a great man; first step in this process was to secure a knighthood for Wright, who was doubtful at first about accepting this honour but afterwards changed his mind. Inoculation remained on a voluntary basis until after his famous *three-column* letter was printed by *The Times* (September 28, 1914). This letter (which is reproduced in full in Colebrook's book) settled the issue, and Kitchener decreed that no soldier was to be sent abroad who had not been inoculated. By the time the war ended, there had been only 1191 deaths from typhoid and paratyphoid in an army of 2 million men; *it is estimated that without inoculation and under conditions of trench warfare there would have been some 967,500 cases and about 125,000 deaths instead of 1191.* (The German Army which invaded France in 1914 went into typhoid-infected terrain without the benefit of inoculation; typhoid caused an alarming number of 'casualties' early in 1915, when the Germans hurriedly adopted immunisation.)

It should be remembered that Almroth Wright waged a great part of his campaign for anti-typhoid vaccination while he was in the employ of the War Office —he was professor of pathology at the Army Medical School from 1892 to 1902. He was a legendary figure in the Army: on one occasion he is supposed to have marched out (in civilian clothes, of course) on to the parade ground and 'plucked' his laboratory technician out of the ranks of soldiers engaged in 'square bashing'. Another wonderful anecdote relates to his appearance before a committee which was considering anti-typhoid inoculation: the chairman asked if he had anything further to tell them, to which Wright replied, "No, Sir, I have given you the facts—I can't give you the brains."

From Netley Wright went to St. Mary's, Paddington, as director in medical charge of the Department for Therapeutic Inoculation. Phagocytosis was one matter which engaged his attention at St. Mary's. Working in conjunction with Capt. Stewart Rankin Douglas, he found that the disposal of microbes by phagocytes was not so simple as Metchnikoff had supposed. In the blood serum there was something which rendered the microbes 'appetising' to the phagocytes; this something he called the *opsonic* property of serum—a pretty piece of word-coining since the Greek word *opsono* means 'I prepare victuals for'.' Colebrook suggests that this discovery was "possibly the most far-reaching since Pasteur's discovery that fermentation was due to bacterial action".

His laboratory became one of the great research centres of the world—his visitors included Robert Koch and Paul Ehrlich (a great friend of Wright's) and Metchnikoff. Among the non-medical men he then knew well were Arthur Balfour, Bernard Shaw and Lord Moulton (the man who took charge of explosives production in the 1914–18 war and afterwards did so much to revive the dyestuffs industry in Britain).

A notable offshoot of Wright's vaccine therapy work was the development of a method of immunising the victims of hay fever against the grass pollens to which they are susceptible. This was done by John Freeman and Leonard Noon, two of Wright's team; later Freeman applied the same technique to the treatment of the whole field of allergic illnesses.

Artificial pneumothorax for tuberculous patients was another technique which owed much to the work of Wright's team, who used it extensively in their research wards.

Colebrook takes great pains to bring out the motives behind Wright's investigations: briefly, to quote his exact words, "Wright was spurred on by the 'pain in the mind' he got from seeing so much sickness in the world." Wright's studies of phagocytosis gave a new and revolutionary conception of the treatment of infectious diseases; he spoke of "calling up the latent forces of the organism"—the human being's own natural powers of antibiosis, so to speak (though it is doubtful whether Wright could have stomached so clumsy a word as antibiosis!). The physician of the future might thus "become an immunisator".

During the 1914–18 war, Almroth Wright spent much time in France. He established a laboratory, on the staff of which were Alexander Fleming, John Freeman and Leonard Colebrook. Harvey Cushing lived there for a while. In Colebrook's words "those were bad days for British surgery", for the usual antiseptics did little good, if any; sometimes they were downright dangerous because they blocked the exits from the wounds and stopped pus getting away. In a classic piece of research Alexander Fleming showed that, at moderate concentrations, carbolic acid in the presence of blood serum considerably favoured growth of one gas-forming bacillus;

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moreover, the growth of this particular microbe could only be suppressed at a concentration of the antiseptic that would have killed a human being inside five minutes! Wright soon saw that "We must first understand the physiological processes going on in the wound." A research programme has developed which studied the physiology—and *ecology*—of wounds. New information about the action of phagocytes—the white blood corpuscles—was obtained. It was discovered, for instance, that the leucocytes exude some anti-bacterial substance which inhibits the growth of bacteria—what we call today a bacteriostatic substance. Out of all this research he devised his slogan for surgeons: "*The leucocyte is the best antiseptic. You must provide the optimal conditions for its functioning.*" It is Colebrook's opinion that "it is probable that Wright's teaching was largely responsible for this very important development of surgical practice"—this development being a surgical technique leaving no 'dead spaces' where bacteria could multiply out of reach of the leucocytes.

'Gas gangrene'—due to an anaerobic bacillus—was another difficult matter which led to some notable researches by Wright and his team.

This review gives some indication of the many interesting *scientific* activities of Almroth Wright which this book describes. But this biography is a full-scale portrait of a *whole* man, and as such it is to be ranked as a rare and fine work.

The Insect Legion: The Significance of the Insignificant

By Dr. Malcolm Burr (*London, James Nisbet, 2nd edn., 1954, 336 pp., 21s.*)

Into this book is crammed a long lifetime of entomological knowledge. Dr. Malcolm Burr as a young man used to correspond with Alfred Russel Wallace, and his own case justifies his remark in the first chapter of this volume to the effect that "Entomology means activity of both brain and body, which is the elixir of longevity. I sometimes think that entomologists must live to an average age of eighty." It certainly appears to be true that entomologists like Dr. Burr retain their enthusiasm throughout the whole of their lives. Anyone who is not ashamed of being appealed to on the grounds of natural curiosity and the sense of wonder at the infinite variety and eccentricity of the insect world will enjoy it. The book has plenty to say about insect pests and the insects that carry diseases, but the author's approach is essentially that of a man who considers that knowledge for knowledge's sake is sufficient reason for studying a scientific subject, regardless of its social and economic impact. Possibly some may object to his two chapter headings 'How Queer!' and 'Still Queerer!' because of modern taboos which suppress the use of words like *queer* and exclamation marks—even though they seem to apply with aptness to such things as the song of crickets (the Japanese organise the equivalent of Edinburgh Festivals with crickets instead of human singers!) and the migration of insects—Dr. Burr mentions the Monarch Butterfly which crossed 1700 miles of sea, though he adds that "it is still doubtful whether one could fly the Atlantic unaided". He gives some fascinating facts in his 'Still Queerer!' chapter about the periodicity of the flashing of fireflies; in a species of *Photinus*, for example, if the fireflies are kept in darkness for 24, 48, 72 or 96 hours, and then brought out into dim light, flashing is induced: it does not occur when the 'dark period' is made 12, 36, 60 or 84 hours. He queries the old idea that Lantern Flies (*Laternaria*) are luminous; this belief goes back to about 1700, but entomologists are far from satisfied that luminescence does occur in the Lantern Flies, though luminescence might occasionally arise through bacterial action—there is a famous sand-hopper which becomes as brilliant as a glow-worm when it is infected with a micro-organism.

The book is full of miscellaneous information of this kind, but even the professional entomologist should find it stimulating as it suggests dozens of ideas which could be investigated experimentally with profit. It should interest—and amuse—anyone who has any natural curiosity about the insects. The fact that it has the character of a miscellany throughout should not be allowed to put anyone off reading this book; after all, Darwin's *Origin of Species* was a miscellany in the literal sense of that term. Dr. Burr has strung the miscellaneous facts together like the beads of a necklace; they make up a reasonably coherent whole as they have been chosen to illustrate some very intriguing themes.

The Dancing Bees

By Professor Karl von Frisch (*London, Methuen, 183 pp., 30 plates, 49 text illustrations, 16s.*)

The World of the Honeybee

By C. G. Butler (*London, Collins, 226 pp., 40 plates, one guinea.*)

Very many books have been written about the honeybee, but that of Professor Karl von Frisch is quite different from any of the others. The book commences with a simple description of the bee colony and of the food and the home life of its members. In the later chapters there is the wonderful story of how honeybees communicate with one another, of how they tell their hivemates what crops to look for and where to go in search of them, of what bees can see and smell and taste, of their sense of time, of how the work of the colony is organised and of how the bees find their way about—all of it is delightfully told by the scientist in whose laboratory these things were discovered.

Although beekeepers will enjoy this book, it is not a book about beekeeping, but a book about bees. It is meant for the ordinary reader, and it will appeal to all who are interested in animal behaviour and natural history. Von Frisch has succeeded in his aim "to give the reader the interesting part of the subject without the ballast of practical instruction that a handbook must provide, without the comprehensiveness of a learned book and the burden of figures, details and documentation with which such a book must be equipped in order to convince". He does not embroider facts with fancy; there is much interesting information, and a welcome absence of speculation, because he rightly considers that "the facts are poetic enough in themselves". His facts are much more strange and interesting than the fancies of earlier bee-writers.

Whereas most of the many books about bees have been written by devotees of the insect, Professor Karl von Frisch brings a unique breadth of vision to his task because he is a famous biologist, and bees are but one of his many interests. This qualification has enabled him to compare the honeybee with other animals, and with humans, and to show where it takes its place in the general scheme of life; this makes the book more interesting and more useful than it would have been if the bee had been considered, *in vacuo*, as some very exceptional curiosity of nature.

This book is now published in English for the first time, but it is a translation of the fifth German edition of the work. The book itself has evolved during thirty years, and new discoveries have been skilfully woven into the original fabric; thus it is in no way unbalanced by von Frisch's own recent epoch-making discoveries, which are given a proper place, but not an over-riding one. In fact, a research worker's criticism of the book might well be that some recent discoveries are not incorporated—for example, the chapter on division of labour is based upon the work of Rösch and there is no mention of the rather different results obtained by Lindauer, and published in 1952 from von Frisch's own laboratory. However, the book is not intended for research workers, but for the general public, and its well-balanced account will exactly meet their requirements.

For the research worker, it has a different kind of interest—he can examine it to see how one great scientist has been able to write a popular account of his subject, in clear and simple language, without any long words or jargon, with no loss of accuracy and with greater gain in understanding.

This work is not only the supreme introduction to a fascinating subject; it is also a model of the way in which popular biology should be written. It is deservedly recommended by The Book Society.

In *The World of the Honeybee* Dr. Butler briefly summarises some of those aspects of the world of the honeybee which are established fact, and devotes most of his space to matters which have been the subject of very recent experiments, and sometimes of controversy. The author surveys his own work, summarises some of the results obtained by others and provides his own interpretations. His views will be interesting to other research workers.

An attractive feature of this book is its selection of photographs, which are of considerable technical merit and have all been taken by the author himself.

C. R. RIBBANDS

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